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A practical guide to the NEW EUROPEAN BAUHAUS self-assessment method and tool

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A practical guide to the New European Bauhaus self-assessment method and tool

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[1] Prof. Jukka Jokilehto passed away on 23rd November 2023. He contributed to 'sense of belonging' aspects of the Beauty dimension.

Contents

Abstract

This handbook provides a complete guide to the New European Bauhaus self-assessment method, designed to promote sustainability, beauty, and inclusiveness in the built environment of Europe and beyond. The handbook comes together with an online tool allowing to evaluate the performance of projects and support their improvement. The online tool is seen as the basis to establish a dialogue between all involved stakeholders, and the grounds for defining minimum performance levels within the New European Bauhaus framework.

Advanced and inclusive targets and indices are proposed to help professionals assess all aspects of the three New European Bauhaus dimensions (Sustainability, Beauty and Inclusiveness) in buildings and living spaces, promote sustainable economic and financial activities, overcome local constraints, and improve the quality of life of the European citizens, indoors and outdoors, through a built environment designed to be affordable, aesthetically appealing, healthy, comfortable, and accessible for everyone. The Beauty dimension of buildings and spaces includes aspects that are difficult to integrate with existing methods, such as sensory perception of space, tangible and non-tangible elements of context, cultural and natural heritage preservation or aesthetical acceptance of reuse and renovation approaches. Beyond aesthetics, the Beauty dimension aims to enhance the quality of experience of the user, addressing safety, performance and functionality under hazards, mitigation of losses, rapid recovery after extreme events, and adaptation to new functions. Inclusiveness stresses the need for affordable and accessible housing units and neighbourhood services that enhance togetherness in European cities and regions. Ultimately, the efficient use of scarce as well as renewable resources and the reduction of the adverse environmental impact, are promoted by new building concepts and by establishing the ground for a truly digital construction ecosystem addressing existing and new buildings as well as living spaces.

Acknowledging the complexity of a thorough and comprehensive evaluation, and understanding the variability of metrics associated with Sustainability, Beauty, and Inclusiveness across different project types, scales, and geographical regions, the self-assessment method is structured hierarchically to provide feedback with three interconnected assessment levels: indicator, key performance indicator, and dimension. Through the integration of contextual variables and the meticulous adjustment of indicators, the method ensures adaptability to the inherent peculiarity of different regions or project settings, while maintaining universality and unity. Specifically, the method defines three spatial scales, namely building, neighbourhood, and urban, and delineates two main project types, namely newbuild and renovation. Supporting the self-assessment process, the online tool ([2]) aims to facilitate the user and simplify the evaluation process while upholding the method integrity and effectiveness. This handbook offers a thorough guidance on the New European Bauhaus self-assessment method and its underlying principles. It covers indicators, assessment targets, key performance indicators, evaluation methods, and measurement units. Additionally, the handbook includes illustrative examples and details the functionality of the online tool, empowering the interested users with the knowledge necessary to perform the evaluation effectively.

The handbook primarily targets professionals engaged in both the delivery phase (design, construction, and commissioning) and the operational phase (operations and maintenance). Specifically, project managers, architects, engineers, and consultants are anticipated to play an active role in gathering and generating the information needed for the self-assessment. However, various stakeholders throughout the entire building lifecycle and supply chains are also expected to participate, benefit from, and be influenced by the assessment, including product manufacturers, main and specialist contractors, policymakers, building users and the local community members directly impacted by the project outcomes. The method is not intended to foster competition or reward high-scoring projects; rather, its purpose is to drive continuous improvement in the built environment quality and align the living environments with the New European Bauhaus objectives. Whereas users are expected to aim at the highest performance in the self-assessment, the decision of focusing more on some performance indicators rather than others is finally left to each user. To emphasise the significance of a balanced performance across all three dimensions of projects, the possibility of obtaining a global performance indicator that would combine the three NEB dimension scores was intentionally excluded.

[2] **NEB self-assessment tool:** https://knowledge-management.new-european-bauhaus.europa.eu/

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Chapter 1: Introduction

1 Introduction

The New European Bauhaus (NEB) initiative (COM, 2021; Report, 2023), characterised by its three dimensions, Sustainability, Beauty and Inclusiveness, seeks to play a critical role in enabling the green transition of the European society, connecting the European Green Deal to buildings, living spaces and experiences (COM, 2019). With this objective in mind, NEB promotes a pivotal transformation of the built environment and fosters its active contribution to meeting climate goals and enhancing the quality of life of all citizens. This is achieved through the development and implementation of an innovative holistic approach to design.

Buildings in the EU are major energy consumers and a significant source of emissions. The NEB Sustainability dimension addresses this by prioritising environmental concerns, including the reduction of energy consumption and emissions, air and water quality, and sustainable use of materials. The NEB approach is aligned with the guiding principle of *Energy Efficiency First* anchored in the EU legislation (Directive, 2023), and focuses on buildings with low energy consumption from both conventional and renewable sources. Efforts concentrate on minimising primary energy demand, reducing electricity peak demand, and optimising smart readiness to efficiently respond to changing conditions, as well as monitoring and adjusting energy flows. Once buildings achieve high energy performance, attention shifts to maximising the share of renewables and integrating energy storage systems to balance the volatility of renewable energy sources. To achieve the EU's climate neutrality goal the Global Warming Potential of the building and the construction products over their entire lifecycle must be reduced. This requires a minimisation of the greenhouse gas emissions, both embodied (i.e. due to original production, construction, maintenance and alteration or end-of-life processes) and operational (i.e. due to heating, cooling, or lighting). Besides energy related aspects, the Sustainability dimension is concerned with air quality and indoor pollution due to their impact on building performance and occupants' health. Moreover, sustainable water consumption and management, along with waste reduction, are crucial challenges addressed. Additionally, economic aspects of sustainability are emphasised, aiming to repurpose, close the loop, and regenerate, promoting circular economy principles in both public and private sectors. The NEB initiative presents an opportunity for Europe to demonstrate its circular economy potential and lead the transition to a circular society.

The NEB framework redefines Beauty in the built environment, recognising it as a crucial aspect of the design, which incorporates both user experience and aesthetics towards the enhancement of user health and wellbeing within living spaces. While recent studies have highlighted the link between aesthetic quality of places and human wellbeing, a significant challenge lies in the absence of unambiguous models to comprehensively assess aesthetics, addressing the diversity of architectural traditions across European regions and beyond. Therefore, robust criteria to evaluate beauty in projects are proposed herein, considering the complex relationships between the users and the surroundings at any scale over time. This entails evaluating the spatial coherence and the sensory perception. Central to this approach is the rediscovery and conservation of cultural and natural heritage as well as the creation of a profound sense of place. However, a positive impact of projects on wellbeing is obtained not only by enriching their aesthetic value but also by improving the quality of experience. Hence, a primary objective of the Beauty dimension is to ensure an adequate level of comfort, health, and safety for all users, regardless of age, ability or background, in both normal and hazardous conditions. Achieving these goals produces high performance environments for living, working, and leisure, but requires a rigorous decision-making in procurement and design processes. Therefore, within the scope of Beauty, the integration of emerging strategies and methods for data acquisition, automation, and digital information analysis is encouraged, and cutting-edge design, construction, and management practices are promoted to optimise the trade-off between quality and resources allocation and consumption.

In addressing Inclusiveness, the NEB paradigm strives to ensure equitable access to project services and opportunities, alongside democratic participation and effective project co-creation and management practices. Market-driven economies and past transformations in the living environments in the era of globalisation have exacerbated inequalities (Dossche et al., 2021), which may intensify with current digital and green transition requirements if not properly tackled. Hence, NEB aligned projects prioritise accessible, high-quality living spaces for all individuals, irrespective of social status, citizenship, age, or gender, aiming to eliminate barriers to access, enhance participation, and actively respond to the expressed needs of groups who may be at a higher risk of exclusion or marginalisation. Good governance practices play a vital role in promoting core principles such as equality, accessibility, and affordability within the Inclusiveness dimension. Existing local, regional, national and EU hard governance processes regulate and influence all the dimensions and respective components of the NEB across design, decision-making, and implementation phases. On the other hand, soft governance practices, including decision-making and capacity building, are crucial for democratic project implementation and stakeholder participation. These practices ensure administrative capacity, responsiveness, transparency and accountability throughout all project phases, ultimately fostering high-quality built environments aligned with NEB principles.

This crucial shift towards a participatory and interdisciplinary decision-making paradigm requires the active engagement of all relevant stakeholders, bridging the gaps across science, technology, art and culture and bringing citizens, experts, businesses, and institutions together to the collaborative creation of a sustainable, inclusive and beautiful future. To facilitate this process, the NEB initiative has established a platform for identification, experimentation and enhancement of good practices. In 2021 the European Commission announced the Commission-led NEB Lab project, which gave rise to the release of the Compass in 2022 (European Commission, 2022). The Compass defines the NEB core ambitions, principles and criteria by illustrating successful examples. Serving as a roadmap for project delivery and operational phases, it offers strategies for implementation, ensuring alignment with the NEB paradigm. Drawing from a wealth of valuable experiences, the Compass provides a clear introduction to the rationale behind the NEB initiative, synthesising insights to inspire decision makers to critically look at their projects and identify areas for improvement. This is achieved by establishing a reference framework and presenting questions and examples. The Compass indicates that a NEB project should embrace three working principles: participatory processes, multilevel engagement and a transdisciplinary approach.

Participatory processes refer to the degree to which the communities affected by the project are involved in the design, decision-making and implementation phases. An essential premise of the NEB paradigm is that a project should always involve civil society or representatives of social groups ('the stakeholders') within a highly participatory framework. Their engagement should be based on equal relations in defining and implementing the project and empower the local community to manage key processes and outcomes, enabling them to initiate and self-govern future actions in the longer term. The ultimate challenge for a multilevel NEB project is to find ways to reach a transformational impact beyond its initial scale, and bridge local and global aspects connecting stakeholders who, across various levels, share similar purposes. Effective multilevel collaboration should produce transferable and scalable solutions to disseminate knowledge in a cross-sectoral manner and activate cross-border experimentation with new ideas. NEB projects should also aim to bring together knowledge and practitioners from various fields, working on solutions that affect different aspects of a project — social, economic, cultural, artistic, architectural, ecological, etc. Transdisciplinary ways of working further encourage solutions that can be applied in a variety of disciplines and fields and are not limited to one area only. A NEB project that starts out as a multidisciplinary collaboration should progress towards integrating results from different disciplines. Ultimately, it should ground scientific expertise in society by drawing on the knowledge of non-academics and the public.

These principles describe the process through which a project should operate and work to achieve the highest level of ambition in the three dimensions. In particular, the NEB Compass delineates three levels of ambition for each dimension and working principle. The first level sets the essential features of a NEB project. Subsequent levels build upon it, aiming for increasingly ambitious goals, with the highest levels representing an ideal outcome. Working at the intersection of the three principles, a project should yield knowledge and insights which can be transferred to other projects or fields of knowledge. The NEB Compass provides guiding questions for each level of ambition. These guiding questions facilitate the project development throughout the entire lifecycle by stimulating fair and careful evaluations of the strategies that can be implemented to fulfil the NEB ambitions. The Compass and its guiding questions delineate the essence of NEB, providing an excellent tool for assessing NEB projects based on qualitative criteria, thus allowing users to subjectively determine the value of projects. Moreover, it paves the way to a subsequent, more detailed assessment framework targeting practitioners. To this end, the comprehensive NEB framework presented in the current handbook aims to streamline standards, guidance and best practice related to the three NEB dimensions, and constitutes the NEB self-assessment method and tool.

Herein, the *method* refers to the approach put forward for the self-assessment of projects according to the NEB principles, including the definition of indicators and their calculation, the combination of indicators in key performance indicators, and obtaining final dimension scores. The *tool* refers to the available complementary online platform allowing the implementation of the method in an ideally automated approach (requesting the necessary input from users and providing the output). The tool is available at: https://knowledge-management.new-european-bauhaus.europa.eu/. It is noted that the method may be applied without the tool. The *Handbook* refers to the present document, which explains the method and provides guidelines for using the tool.

The New European Bauhaus self-assessment method was envisaged to evaluate where a project or activity stands in relation to the NEB dimensions. This is a groundbreaking, multidisciplinary, comprehensive and synergistic approach for the evaluation of projects and activities under the NEB values, principles and ambitions. The method comprises a set of harmonised measurable criteria (i.e. key performance indicators) and specific thresholds, meant to quantify the quality of a project according to specific dimension assessment targets. The key performance indicators are designed based on key aspects relevant to the objectives defined for each dimension, and responding to specific challenges using the NEB ways and approaches. All the assessment targets empower and integrate criteria described by EU policies and resources. Representative examples include the European quality principles for EU-funded interventions with potential impact upon cultural heritage by ICOMOS (Dimitrova et al., 2020), the 2018 and 2023 Davos Declarations and the Davos Baukultur Quality System (SFoC, 2018, 2021, 2023), the report on high-quality architecture and built environment and its self-assessment tool developed by the Open Method of Coordination (OMC) group of EU Member State experts (European Commission, 2021), the Green Public Procurement scheme (European Commission, 2023), and the Level(s) framework (De Wolf et al., 2023). In particular, the self-assessment method incorporates the common language for describing the sustainability performance of buildings and some indicators and systems for measuring the components of this performance developed within Level(s). Moreover, it integrates relevant metrics and strategies inspired in well-established international frameworks, i.e. the certification tools administered by the members of the World Green Building Council global network, such as BREEAM([3]), CASBEE([4]), DGNB([5]), LEED([6]) and WELL([7]). By seeking synergies with these initiatives, the NEB self-assessment method aligns with established standards, combining, balancing and expanding them to ensure a consistent and comprehensive evaluation of Sustainability, Beauty and Inclusiveness. This process requires the definition of an overarching common understanding and a broad-scope shared culture of high-quality architecture and built environment. By doing so, it ensures a quantitative assessment of environmental performance, health and comfort and life cycle cost and value, without overlooking crucial aspects, such as social equity, aesthetic quality, or resilience against evolving hazard scenarios.

The ultimate goal of the NEB quantitative assessment should not be seen as fostering a competitive environment based on ratings, in which projects with higher scores obtain a better certification level or recognition from a third-party assessor after the construction. The method rather focuses on facilitating the self-assessment carried out by the same parties involved in the design and delivery of the project, fostering the continuous and informed improvement of its performance in terms of NEB principles. Hence, it guides the decision-making among alternative solutions and ensures a balanced trade-off between potentially conflicting objectives during the design stage. Furthermore, the self-assessment method is both accessible and affordable, as it is not associated with fees or implementation costs, which can be prohibitive for smaller projects or organisations with limited budgets.

Inevitably, such an all-encompassing procedure may be demanding and time-consuming, requiring close collaboration among diverse stakeholders for meticulous documentation, transdisciplinary analyses, and detailed verifications. This level of complexity may discourage individual users lacking the necessary technical knowledge from using it without specific assistance. Therefore, while crafting the self-assessment method, a key objective has been to streamline the evaluation process and ensure an effective support to a wide range of technical and non-technical stakeholders, simplifying the assessment process without compromising the comprehensive coverage of the assessment targets. In this context, the development of an automated online tool is pivotal in making the process more user-friendly, enhancing efficiency and facilitating the dissemination and exploitation of the NEB self-assessment method.

The present document serves as a user manual, collecting and explaining the assessment targets pursued by the NEB method. It includes a description of the overall methodology, justification of the relevance of key performance indicators, explanations of what they measure, details on their evaluation, a description of the employed unit of measurement and references to relevant standards, codes and best practice. Furthermore, it provides explicit and practical instructions on how to measure and combine them into univocal dimension scores. Hypothetical examples of the key performance indicators evaluation are provided, which draws upon example calculations from the metrics or standards adopted in each indicator. The handbook is purposefully designed to offer guidance and additional information for quantitative evaluation and application to building and living space projects.

Following this introduction, Chapter 2 presents an overview of the proposed self-assessment method and its main features. Chapters 3, 4 and 5 provide a detailed description of the selected indicators and key performance

[3] https://breeam.com.
[4] https://www.ibecs.or.jp/CASBEE/english/.
[5] https://www.dgnb.de/en.
[6] https://www.usgbc.org/leed.
[7] https://www.wellcertified.com/.

indicators by the dimensions of Sustainability, Beauty, and Inclusiveness, respectively. Finally, Chapter 6 outlines the main concluding remarks on the efficacy of the proposed method.

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List of abbreviations and definitions

COM	Commission communication
ICOMOS	International Council on Monuments and Sites
NEB	New European Bauhaus
OMC	Open Method of Coordination group of EU Member State experts
SFoC	Swiss Federal Office of Culture

Chapter 2:
A NEB self-assessment method

2 A NEB self-assessment method

2.1 Overview and rationale

Self-evaluation of proposed projects forms an essential task, required to assess the relative success of project objectives, and implement appropriate modifications and improvements to enhance their overall performance.

The aim of the self-assessment method should not be perceived as creating a competitive environment among participating projects but rather measuring compliance with the NEB principles, locating potential deficiencies, and identifying the areas and the means for projects to improve their performance. Ultimately, the objective is to increase the positive impact of projects by promoting NEB principles in an effective way. The method is further expected to create a common language and understanding, facilitating the dialogue between disciplines and stakeholders, as well as to establish the grounds for future definition of minimum performance levels.

The self-assessment method consists of a hierarchical structure with different assessment levels that underpin the three dimensions of Sustainability, Beauty and Inclusiveness. In support of the aim of the method, the highest level of assessment does not include an integration of dimensions, which could eventually drive the use of a method into a competitive context while potentially concealing major deficiencies of projects. Therefore, the main assessment levels, starting from the lowest, are the *indicator*, the *key performance indicator* (KPI) and the *dimension* levels. The three assessment levels are interrelated. The first level of indicators represents the entry point, where input data are required by the user. The performance of projects regarding individual dimension targets defines the KPI assessment level, where KPIs reflect aggregate performance over a number of different indicators that comprise a target. Finally, at the highest dimension level, the holistic performance of projects is assessed as an aggregate over the targets set by the dimension.

Indicators assess specialised attributes of projects, such as energy demand, hazard resilience, visual experience of architecture and space, and preventive measures for segregation. Within the self-assessment method, indicators take various forms. Indicators can be mathematical operations combining several metrics, which in turn are a function of sub-metrics etc. Metrics and sub-metrics are calculated by the user through simulations (e.g. energy performance assessment using engineering software), measurements (e.g. energy bills when assessing an existing building), or simply numerical input based on project design data (e.g. floor area) and parameters (e.g. primary energy factors) defined by codes, standards, or other sources. Indicators of this form are normalised to express improvement relative to a baseline (thus consider context, Section 2.3.3), or they are estimated as a percentage of a project variable to indicate performance (e.g. green funding as percentage of private investment). In both cases, the *indicator score* varies within a 0–100 range. As implied by the provided examples, this purely quantitative approach is typically (but not always) the case of Sustainability indicators.

Alternatively, indicators can follow an expert opinion-based approach, which associates indicator score to a series of user responses to multiple choice questions. In this alternative, such questions represent the relevant metrics and sub-metrics, whereas, the indicator score, ranging also within 0–100, is an aggregation of *metric (and sub-metric) scores*. In highly regulated aspects of Beauty (e.g. safety, resilience, functionality), metrics typically evaluate compliance to project design requirements set by codes and standards and high-quality certification schemes such as BREEAM ([1]), LEED ([2]) and DGNB ([3]). The highest the quality of design requirements, the highest the score assigned through expert opinion to the metric. Since over time, standards and guidelines are superseded, the evaluation of indicators based on these should refer to their most recent versions. Within less or non-regulated aspects of Beauty and predominantly in Inclusiveness, metrics measure compliance to best practice, defined on the basis of thorough state-of-the-art reviews on existing knowledge and challenges, as well as expert judgement.

Within each dimension, concrete assessment targets are defined. Each target is described by a key performance indicator, which assesses the performance of projects in a broader subject of the dimension (compared to indicators), e.g. digitalisation in construction, spatial coherence in planning and design (both KPIs within the Beauty dimension). In mathematical terms, the *key performance indicator score* is a weighted average of indicator scores, where *indicator weights* reflect indicator significance. KPI scores (numerical values) are associated through specific *KPI thresholds* with *KPI performance classes*, which are qualitative measures of performance (e.g. Low, Acceptable performance). Subsequently, KPI scores are transformed into KPI *performance class scores* (numerical values) as a function of the attained performance class, to allow the calculation of the dimension score at the final assessment level. KPI performance class scores are common

1 https://breeam.com.
2 https://www.usgbc.org/leed.
3 https://www.dgnb.de/en.

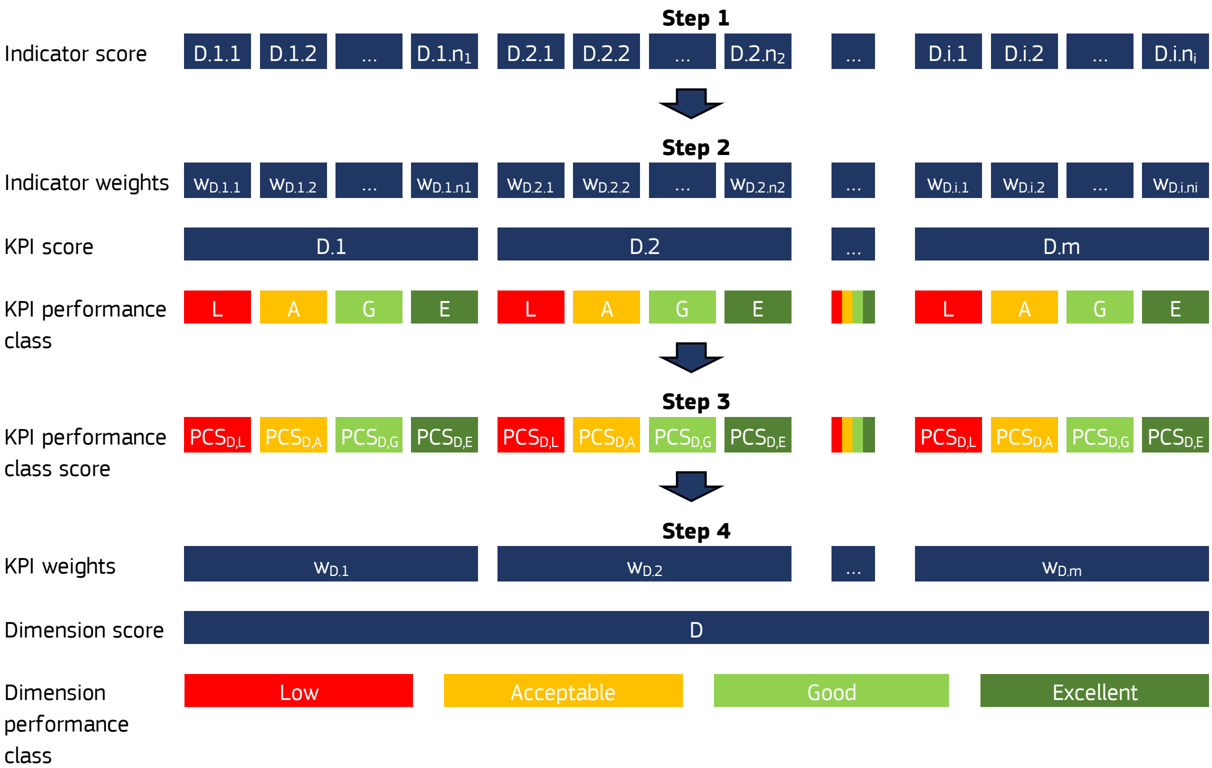
across all the KPIs of a single dimension, i.e. all KPIs of a dimension with an Acceptable performance class are assigned with the same performance class score. The reason behind such transformations lies in a systematic effort to handle uncertainty and avoid a false sense of accuracy, given the diversity of indicator formats that is inevitably introduced due the multidisciplinary nature of the New European Bauhaus.

Eventually, the *dimension score* derives as a function of a well-defined set of KPIs (more precisely, KPI performance class scores). Considering that specific KPIs in a dimension may have a higher impact on aligning with NEB, their relative significance is expressed through dedicated *KPI weights*. By combining KPI performance class scores with the corresponding KPI weights in a dimension, the dimension score is estimated (once again in a 0–100 range). Similarly to KPIs, the dimension score is transformed through *dimension thresholds* into a dimension performance class, which indicates the success of projects over the set dimension targets.

2.2 Assessment steps

The proposed self-assessment method involves four hierarchical steps that are schematically presented in Figure 1. The steps roughly correspond to the assessment levels, i.e. evaluation of (*i*) indicator scores, (*ii*) KPI performance classes, (*iii*) KPI performance class scores, and (*iv*) dimension performance class. The discrete steps are described in Sections 2.2.1–2.2.4.

Figure 1. Overview of the NEB self-assessment method



Source: JRC.

Prior to commencing with the implementation of steps, the user needs to classify the considered project in terms of spatial scale, type and main use according to Table 1.

Table 1. Classification of considered projects.

Spatial scale	Type	Main-use
Building	New built	Residential (mainly)
Neighbourhood	Renovation	Non-residential (mainly)
Urban		

Source: JRC.

The classification of the project will impact the self-assessment process in various ways, including the modification of indicator weights, KPI weights, and KPI thresholds. The project classification may further affect the definition of indicators, along with their inclusion/exclusion in the calculation of KPI scores. Classification is further discussed in Section 2.3. The field of application of each indicator is provided in Chapters 3–5.

According to the following steps (Sections 2.2.1–2.2.4), the methodology is based on predefined KPI and dimension thresholds as well as indicator and KPI weights. Although the definition of thresholds and weights is based on the best possible expertise and knowledge of the expert group, the provided thresholds may not adequately address projects characterised by immense regional or local specificities. Nevertheless, an effort was made to address to a certain degree the context of projects through normalisations of scores to baselines values and questions assessing the context prior to evaluating indicators (Section 2.3.3).

2.2.1 Step 1 – Evaluation of indicator scores

Indicator scores should be evaluated ideally across all three dimensions, or in the dimension(s) of interest. They are a function (*f*) of metrics (*M*) and sub-metrics (*SM*) following the generic form of Equation (1).

$$D.i.j = f(M_1, M_2, \dots, M_k) = f[M_1, (SM_{2.1}, SM_{2.2}, .., SM_{2.l}), \dots, M_k] \qquad (1)$$

Indicators are encoded with the three-level code *D.i.j*. In this sequence, *D* may take any of the values of S, B, I, indicating the dimensions of Sustainability, Beauty and Inclusiveness, respectively. The term *i* indicates the ordinal number of the parent key performance indicator, whereas the term *j* indicates the ordinal number of the considered indicator.

The evaluation of indicators is described in detail by dimension and KPI in Chapters 3–5. The chapters provide all the necessary information about the required user input depending on the indicator format.

2.2.2 Step 2 – Evaluation of KPI scores and performance classes

Key performance indicator scores should be evaluated ideally across all three dimensions, or in the dimension(s) of interest. KPI scores are defined as a weighted average of indicator scores, following the generic form of Equation (2).

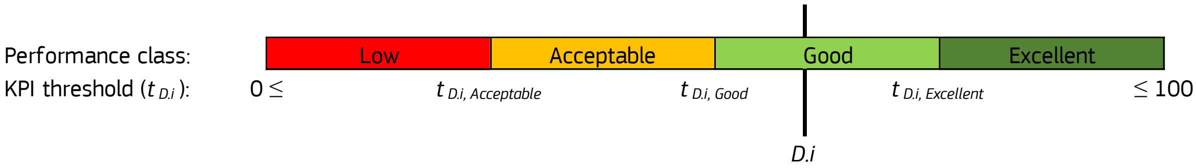
$$D.i = \sum_{j=1}^{n} \left(w_{D.i.j} \cdot D.i.j\right) \Big/ \sum_{j=1}^{n} \left(w_{D.i.j}\right) \qquad (2)$$

KPIs are encoded with the two-level code *D.i*, where *D* indicates the dimension (i.e. S, B, or I) and *i* the ordinal number of the considered KPI that aggregates *n* indicators. $w_{D.i.j}$ represents the weight (i.e. significance) of indicator *D.i.j*. Indicator weights are provided by the method as fixed values with a range of 0–1 and a sum equal to unity.

In Beauty and Inclusiveness dimensions, when all indicators apply to a project, the denominator of Equation (2) equals unity. However, when an indicator is eliminated (omitted) from Equation (2) because it is not relevant to the project scale, type or use, the denominator will be lower than unity, thus enabling a proper rescaling of weights of the remaining indicators. In the Sustainability dimension, the indicator weights are explicitly defined for all the potential combinations of project scales, types and uses. In each of these combinations in Sustainability, the denominator of Equation (2) equals unity.

With the aid of KPI thresholds ($t_{D.i}$), four performance classes are introduced according to Figure 2, i.e. *Low*, *Acceptable*, *Good* and *Excellent*. Performance classes represent qualitative measures of performance that nonetheless correspond to a range of the KPI scores. The threshold values defining the range of each performance class are fixed for each KPI, ranging between 0 and 100, and typically differ among the KPIs in each dimension.

Figure 2. Performance classes and thresholds for KPI *D.i*.



Source: JRC.

Considering each KPI score and thresholds, the KPI performance class is assessed. In the example of Figure 2, the performance class of *D.i* is Good, since $t_{D.i,\ Good} \leq D.i < t_{D.i,\ Excellent}$. The process should be repeated so that a performance class is assigned to each KPI.

Overall, it is highly recommended that all KPIs attain as a minimum the *Acceptable* performance class. Within the IT tool, the user may proceed with the self-assessment in all cases, but a warning will appear in the cases of KPIs with *Low* performance classes recommending an upgrade to the Acceptable class. Ideally, projects should seek to attain the *Excellent* performance class in all KPIs, whereas in practice the decision of focusing more on some KPIs rather than others is finally left to the involved stakeholders. Nonetheless, efforts and resource allocation to achieve higher scores in a few KPIs should never come at the expense of others, so that overall a balanced and high-quality outcome is attained across all dimensions.

The evaluation of KPI scores is described in detail by dimension in Chapters 3–5. The relevant sections within these chapters further provide the indicator weights ($w_{D.i.j}$) and the performance class thresholds per KPI ($t_{D.i}$).

2.2.3 Step 3 – Evaluation of KPI performance class scores

In this step, a performance class score is assigned to each KPI, as a function of the attained performance class, evaluated in Step 2. The KPI performance class score replaces the KPI score in the remaining steps of the self-evaluation method as a means to handle uncertainty in calculations and mitigate the effect of employing diverse indicator formats. KPI performance class scores vary within a 0–100 range and depend only on performance classes and dimensions (i.e. they are common to all KPIs within a single dimension. For example, all KPIs within the Sustainability dimension that attain the *Good* performance class are assigned with a $PCS_{S,\ Good}$ = 80. The performance class scores per dimension and performance class are provided in Figure 3.

Figure 3. KPI performance class scores (PCS) per dimension and performance class.

Performance class:	Low	Acceptable	Good	Excellent
Sustainability	25	45	70	100
Beauty	0	40	70	100
Inclusiveness	10	45	75	100

Source: JRC.

2.2.4 Step 4 – Evaluation of dimension scores and performance classes

Dimension scores are defined as a weighted average of KPI performance class scores, following the generic form of Equation (3).

$$D = \sum_{i=1}^{m} (w_{D.i} \cdot PCS_{D.i}) \bigg/ \sum_{i=1}^{m} (w_{D.i}) \qquad (3)$$

Dimensions are encoded with the single-level code *D*, indicating the dimension (i.e. S, B, or I) that aggregates *m* key performance indicators. $w_{D.i}$ represents the weight of the key performance indicator *D.i*, multiplied with the KPI performance class score $PCS_{D.i}$ (obtained from Step 3). Key performance indicator weights are provided by the method as fixed values with a range of 0–1 and a sum equal to unity.

In Beauty and Inclusiveness dimensions, when all KPIs apply to a project, the denominator of Equation (3) equals unity. However, when a KPI is eliminated from Equation (3) because all the integrated indicators (hence the KPI) are not relevant to the project scale, type or use under investigation, the denominator will be lower than unity. This approach enables a proper rescaling of weights of the remaining (relevant) KPIs. In the Sustainability dimension, the KPI weights are explicitly defined for all the potential combinations of project scales, types and uses. In each of these combinations in Sustainability, the denominator of Equation (3) equals unity.

With the aid of dimension thresholds (t_D), four performance classes are introduced according to Figure 4, i.e. *Low*, *Acceptable*, *Good* and *Excellent*. The threshold values defining the range of each performance class are fixed for each dimension (in a 0–100 range) according to Figure 4.

Figure 4. Dimension performance classes and thresholds for Sustainability, Beauty and Inclusiveness.

Performance class:	Low	Acceptable	Good	Excellent	
Dimension threshold:	0 ≤	$t_{D, Acceptable}$	$t_{D, Good}$	$t_{D, Excellent}$	≤ 100
Sustainability (t_S):		≥ 40	≥ 60	≥ 80	
Beauty (t_B):		≥ 40	≥ 65	≥ 85	
Inclusiveness (t_I):		≥ 40	≥ 60	≥ 80	

Source: JRC.

Considering each dimension score and thresholds, the dimension performance class is assessed. In the illustrative example of Figure 4, the performance class of dimension D is Good, since $t_{D,\ Good} \leq D < t_{D,\ Excellent}$. The process should be repeated so that a performance class is assigned to each dimension.

The evaluation of KPI scores is described in detail by dimension in Chapters 3–5. The KPI weights (t_D) are provided in Sections 3.3, 4.3, 5.3.

2.2.5 Output

The self-assessment method provides a useful tool to evaluate specific and global performances of projects for the three NEB dimensions. Scores are estimated for all indicators, KPIs and dimensions, however, eventually projects are evaluated in qualitative terms, considering the attained KPI and dimension performance classes to minimise the impact of calculation and input uncertainties. In this context, KPI and dimension performance classes represent the main output of the method. Nevertheless, the self-assessment method provides the user with all the required quantitative and qualitative outputs to evaluate the overall performance, thus increasing the chances of success.

2.3 Project classification

The field of application of the NEB self-assessment method needs to be broad to accommodate the assessment of projects that can be diverse in many terms: spatial scale, project type and use, among others, such as ambitions to accomplish, management agents and stakeholders. This diversity of projects is further enriched by the wealth of 'forces' and resources that should contribute to the new design or reshaping of the built environment and living spaces in ways that are, at the same time, sustainable, beautiful and inclusive. Overall, the approach of the NEB self-assessment method is common, applied in the same way across projects when their diverse features are not — or should not — create a difference in their assessed performance. However, some specific features of the assessed projects have to be taken into account in order to increase the relevance and value of the self-assessment process. Different projects need different indicators to assess their performance, and this is built in the structure of the self-assessment method in terms of project spatial scale, project type and project main use, as presented in Table 1.

The classification of the project is performed by the user before implementing the assessment steps (described in Section 2.2.2). Following the classification, the non-relevant indicators and KPIs, i.e. those that do not apply to the selected project class, are filtered out (i.e. omitted) from the calculation process. Filtering concerns the self-assessment primarily at the level of indicators. On a few occasions, all relevant indicators of a KPI may be omitted, which results in omitting the relevant KPI from the calculation of the dimension score (Section 2.2.4). Additionally, on a few occasions in Beauty and Inclusiveness, an indicator may be omitted depending on projects aspects that are not (only) related to the project scale, type and main use. For example, the indicator of compliance with material efficiency opportunities (B.2.3) applies to renovation projects only when these include alterations to the floor system. The remaining (relevant) indicators are combined using indicator weights to form KPIs, which in turn are combined with KPI weights to evaluate the dimension. In this process, indicator weights, KPI weights, and KPI performance class thresholds (in Sustainability dimension only) vary depending on the project classification. The project class may further affect the definition of the remaining relevant indicators. For example, an indicator may be relevant for all project scales but its calculation changes, when the calculation of one or more metrics is also affected by the project scale. Filtering out indicators and application of the proper weights and thresholds is fully automated on the online NEB self-assessment tool.

2.3.1 Project spatial scale

In the NEB self-assessment method, distinguishing the spatial scale of the project is crucial, as specific aspects described by key performance indicators, indicators or metrics within the Sustainability, Beauty and Inclusiveness dimensions may vary substantially at different scales. Relevant background documents to the New European Bauhaus initiative and the self-assessment method address the notion of *spatial scale*. For instance, the New Leipzig Charter (FMI, 2020) indicates that measures focusing on local developments should be designed at the appropriate spatial scale, i.e. at the level of neighbourhoods, as well as wider functional, regional and metropolitan scales. Further references to spatial scales can be found in the Davos Declaration (SFoC, 2021) and the work of the OMC group of Member States' experts towards a high-quality architecture and built environment for everyone (European Commission, 2021). The OMC groups notes that "*the quality of housing and its surroundings, as well as their governance, at different scales (building, city, region), have been shown to exist in a fragile reality which has highlighted the need to pay greater attention when planning the living environment*". The same document also emphasises the necessity to work "*at different scales concerning neighbourhoods, villages, cities, infrastructure and landscapes*" in relation to reuse, regeneration, retrofitting and revitalisation of existing buildings, which is one of the crucial targets of the NEB (European Commission, 2021). Several considerations of spatial scales appear in the context of *place*. Place is defined as a section of space that varies in scale, size and typology, spanning interiors, single and multipart buildings, urban fabric, neighbourhoods, regions, infrastructures, public places, green spaces and cultural landscapes, all including their respective setting and context (SFoC, 2021). In the NEB Compass, scale is considered at the various levels of ambition (European Commission, 2022). In particular, the Compass refers to *multilevel engagement*, emphasising the need to involve the citizens beyond the scale of the projects itself (from local to regional, from national to international, etc.).

The NEB self-assessment method integrates three spatial scales to characterise the size of the project and the area affected by the project, i.e. building, neighbourhood, and urban (Table 1). For the sake of clarity, it is underlined that all scales may integrate surroundings, but the considered projects should have a focus on the built environment.

In the self-assessment method, the *building* scale refers to projects affecting single building units and their potential surroundings, regardless of their specific function. For instance, a single-family dwelling and a large-scale multifunctional building, such as a museum or a shopping gallery comprising commercial, administrative and recreational areas, are both classified as building-scale projects. The building scale boundaries depend on the aspect being assessed each time by a KPI, indicator, or metric. For instance, when assessing aesthetic acceptance of an architecture (i.e. B.7), the user will analyse the building within wider boundaries than the ones applied for the thermal performance of the building envelope, since the visual experience of architecture at building scale includes attractiveness of circulation, expanding the building boundaries to its surroundings, and uncovered parts such as patios, terraces, adjusted green areas, etc. Almost all indicators in the NEB self-assessment method are designed to be implemented at the building scale. Their extension to a higher scale is modelled following various approaches that are described later in the current section. On very few occasions, indicators are applicable and meaningful only at the building scale.

The *neighbourhood* scale refers to projects involving parts of a village or city (European Commission, 2021), extending beyond the individual building scale, yet addressing an area with strong interactions of the residents, a sense of shared identity, common facilities and similar social characteristics. Due to the interconnected environmental, cultural, social, political and economic conditions as well as resources and opportunities within a neighbourhood, projects at this scale are primary drivers of sustainable community redevelopment (Holden, 2018). However, this spatial scale is a multifaceted concept, since its identification requires understanding the dimensions and characteristics that contribute to the concept of a neighbourhood. The neighbourhood scale encompasses factors like social interactions, diversity, democratic participation, local governance, and communication. Even though natural and administrative boundaries, streets or landmarks are often used to define the neighbourhoods, they may not accurately capture the essence of a neighbourhood. Thus, understanding how residents perceive their neighbourhood boundaries provides a more solid foundation for research and practice, and as such it may be used for the purpose of the self-assessment method equally well as a neighbourhood defined by administrative boundaries. Accordingly, a project that consists of a couple of buildings, a block of buildings or multiple blocks of buildings are all classified into the neighbourhood scale.

Within the NEB self-assessment method, the neighbourhood scale is modelled using three broad approaches that consider the specificities of diverse indicators. According to the first two approaches, indicators that were originally designed for the building scale are extended to apply to the neighbourhood scale. The assessment of indicators focuses on representative (physical or non-physical) attributes of the built environment within the neighbourhood.

The first approach makes use of 'average' or most-dominant attributes of the built environment within the assessed neighbourhood to estimate an indicator. For example, the indicator of spatial coherence and urban cohesion (i.e. B.8.1 in Beauty dimension) requires, among others, an estimate of the average height of the buildings in the assessed neighbourhood (to compare it with the average height of the building in the broader urban environment). The primary energy demand indicator (S.1.1 in Sustainability dimension) requires a quantification of the delivered energy demand for all buildings within the neighbourhood, normalised to the number of inhabitants.

In the second approach, the user is required to perform multiple assessments for buildings with distinct characteristics defined on the basis of representative physical or non-physical attributes of the built environment within the neighbourhood. In this case, the indicator score is estimated as a weighted average of the indicator scores corresponding to the separate assessments. Weights can be based on the relative occurrence of each building (in terms of number of buildings, built area, or other feature). The average indicator score is then used to estimate the KPI score according to the steps of Section 2.2. The second approach is present in indicators within the Beauty dimension, relevant to aspects of quality of experience (e.g. quality of design and construction, resilience to hazards etc.), and to some extent within Sustainability and Inclusiveness. Interestingly, in Inclusiveness, the same approach can apply to building scale projects, as the unit of reference is the housing unit (dwelling), and therefore the multiple assessments refer to housing units with distinct (typically non-physical) attributes, such as tenure type. Within these indicators in all dimensions, typically the user is also given the alternative option to assess a single building or housing unit that can represent on average the different attributes or integrates the most dominant ones within the assessed project, which is practically aligned with the first approach.

According to the third approach, indicators are either ad hoc designed to be assessed at the neighbourhood scale focusing on specific scale-relevant aspects, or they are designed to apply to all scales as practically they are not explicitly affected by the size of projects. Typical examples are indicators within the Inclusiveness dimension. For instance, preventing gentrification and displacement (i.e. I.5.3) is not meaningful for the building and urban scales. On the other hand, the indicator of main funding channels (i.e. I.1.1) assesses the types of project funding as a means to promote non-financial, non-speculative financial circuits and prevent the growth of spatial inequalities. As it is independent of project size, it applies seamlessly to all scales.

The *urban* scale is directly linked to projects involving a larger portion of the city. While in general understanding a city is a large and densely populated area that has its own government and powers granted by the state or country, legal definitions of a city range from those using a single criterion (e.g. population threshold) to those using a mix of criteria (e.g. combination of population size, density, administrative delimitation, sources of income and main professions) (UN-Habitat, 2018). The European Commission differentiates the *degree of urbanisation* (DEGURBA) in *local administrative units* (LAUs) between urban and rural areas. This classification is a function of population within low density (rural) grid cells, moderate density (urban) clusters, and high-density clusters (urban centres) comprising LAUs (Regulation, 2017).

Grid cells and clusters are defined as (Commission Implementing Regulation, 2019):

— *Low density or rural grid cell*: 1 km^2 grid cells with density below 300 inhabitants/km^2 and other cells outside urban clusters.

— *Moderate density or urban cluster*: Contiguous 1 km^2 grid cells with a density of at least 300 inhabitants/km^2, and a minimum of 5000 inhabitants in the cluster.

— *High density cluster or urban centre*: Contiguous 1 km^2 grid cells within the urban cluster with a density of at least 1500 inhabitants/km^2, and a minimum of 50 000 inhabitants in the cluster after gap filling.

LAUs are classified based on their degree of urbanisation into:

— *Rural or thinly populated areas:* at least 50% of the population lives in rural grid cells.

— *Urban areas*:

  - *Intermediate density area or towns and suburbs*: less than 50% of the population lives in rural grid cells and less than 50% live in urban centres.

- *Densely populated areas or cities*: at least 50% of the population lives in urban centres.

The urban scale is also specified in functional terms, especially for large urban agglomerations. Functional Urban Areas (FUAs) are bringing together core and commuting areas (Dijkstra et al, 2019). This definition of urban scale provides a common approach to the delimitation of the very diverse large cities across the world and distinguishes the degree of urbanisation within urban areas between core and commuting zones.

Considering the NEB self-assessment method, urban scale projects integrate the built environment and living spaces within urban areas, while projects involving rural or thinly populated areas may be considered at the neighbourhood scale. For example, a project in support of adaptation strategies in the built environment uses parametrically designed shading to protect building facades and public spaces from overheating. As the project extends throughout main streets and squares of a mid-scale city, it is classified as an urban-scale project.

Within the NEB self-assessment method, the urban scale is modelled using the same approaches that were described earlier in this section for the neighbourhood scale. Further details are provided for each indicator in Chapters 3–5.

2.3.2 Project type and main use

Besides the spatial scale, in the NEB self-assessment method, the project type and main use are important characteristics of the project that drive the formulation of KPIs, based on filtering indicators within the Sustainability, Beauty and Inclusiveness dimensions. Similarly to project scale, the classification of projects among different types and uses is employed to increase the relevance and value of the self-assessment process.

Projects are classified according to their *type* into newbuilds and renovations (Table 1). The differentiation is based on whether a project targets new construction, i.e. design and development of new buildings and living spaces, or targets renovation, i.e. reusing, retrofitting of existing buildings and living spaces. If a neighbourhood or urban scale project comprises both new constructions and renovation works, the user should classify the project based on the most dominant aspect. Alternatively, the user may opt to assess the project as two individual projects, one addressing newbuilds, and one addressing renovations, both assessed at the scale of the complete project.

The project type affects the assessment process in different ways for each dimension. In Sustainability, the assessment of newbuild and renovation projects is implemented in different ways regarding the KPIs/indicators considering the materials used in the process. However, the assessment of a major renovation project will take into account only the new materials used in the process in the same way the online tool would do for a new construction project. In the Beauty dimension, the type of project is mainly relevant for indicators that apply exclusively to projects related to cultural heritage, where renovation is the only eligible option. For the rest of the Beauty indicators, the project type does not affect the evaluation, i.e. the assessment of newbuild and renovation projects is the same. However, in the case of renovations, the focus is on the specific aspects of the building and spaces that are affected by the renovation works. When indicators and/or metrics address aspects that have not been altered by the renovation, yet influence the performance under a specific assessment target, they are assessed considering the condition existing before the renovation and still present in the building. Finally in Inclusiveness, the project type does not affect the evaluation apart from a single indicator.

Projects are further classified depending on main use into residential and non-residential projects. Non-residential projects refer to commercial use (e.g. offices, wholesale and retail, hotels) and do not address industrial use (e.g. manufacturing facilities, power plants, refineries). However, decommissioned industrial facilities and spaces renovated to serve residential or commercial use can be evaluated with the NEB self-assessment method.

The need for this distinction among residential and non-residential projects according to the aforementioned definitions is mainly associated with the Inclusiveness dimension and the fact that residential buildings are related to accessibility and affordability of housing as a fundamental human right. Commercial use of buildings may also be related to the target of inclusive building spaces, but their accessibility is evaluated differently. In the Sustainability dimension, the distinction is reflected in the formulation of the KPIs, considering that the different building uses are likely presenting different services, energy demand, greenhouse gas emissions or indoor air quality requirements, among others. Finally, in the Beauty dimension the project main use does not affect the assessment process. If a building, neighbourhood or urban scale project includes buildings and/or spaces with mixed use (e.g. a building with apartments and offices, or a neighbourhood with office and residential buildings), the user will need to classify the project based on the most dominant aspect (similarly to project type). Alternatively, the user may opt to assess the project as two individual projects, one addressing residential use (e.g. neighbourhood and residential), and one addressing non-residential use (e.g. neighbourhood and non-residential), both assessed at the scale of the complete project. Likewise, if a project combines multiple types and main uses, it can be assessed as multiple projects addressing separately the different classes (e.g. newbuild and residential; newbuild and non-residential; renovation and residential; renovation and non-residential) at the scale of the complete project.

2.3.3 Context

The projects, which can be evaluated through the New European Bauhaus self-assessment method, may be operating within very different contexts. Various contextual features imply different conditions for the implementation of the assessed projects. For example, the very different climatic conditions in Northern and Southern Europe imply a different project strategy in terms of materials and technologies for energy monitoring and, potentially, in economic terms. Another example of context affecting the self-assessment outcome is the difference between regions of Western and Northern Europe following the rationale of housing allocation according to public/social housing principles, and regions of Eastern and Southern Europe where housing is mainly allocated according to market criteria and mechanisms.

Contextual differences, like those mentioned, will inevitably affect the performance of projects. The question is how these inevitable contextual effects can be handled and modelled within the self-assessment method. A project in a Northern European country planning several heating energy-efficient measures would attain higher scores than a project in a warmer climate, if the diverse and unequal contextual conditions are not considered. Likewise, a project planning to use the numerous options to improve its affordability within a context of a strong public/social housing system would score much higher than a project operating within a housing system where such options are scarce, if context is ignored. The self-assessment method takes into account these contextual differences, as much as possible. The purpose is to avoid measuring the conformity of contexts to NEB principles, and rather focus on the effort of projects to comply with and promote these principles.

There are different ways in which the self-assessment method considers contextual differences. The details are provided in the description of all indicators that need to be contextualised (Chapters 3–5). The rationale, however, is common: when an indicator needs to be contextualised, a contextual variable is set up and used to adjust the score of the indicator. For example, an indicator evaluating housing affordability as the percentage of housing units planned to be allocated through the market and those through public/social housing mechanisms, will be adjusted according to the existing housing system wherein the assessed project operates. More precisely, two projects providing the same percentage of affordable housing (i.e., below market prices/rents) will not get the same score if the first operates within a favourable (universalist) housing system, and the second in an unfavourable (residualist) system. The second will get a higher score underlying a higher effort and a greater impact in promoting NEB principles within a negative context. Another example is a project operating within a context where legislation and regulations about sustainable building are developed and adopted as part of a growing culture/practice, where sustainable materials are abundant and affordable and the know-how of their use is developed, compared to a project operating in a context where these conditions are much less developed. In a similar way, the score of a project following sustainable construction options within a context that does not promote them and does not enable their use will be boosted compared to a project with the same score operating in a favourable context.

Contextual factors include the type of hazards that can affect a project, i.e. fire, blast, wind, floods (riverine and coastal), earthquakes, landslides, volcanic ash and tsunami. The risk assessment of building damage and collapse depends on the type of hazards anticipated, as different ones pose varying levels of threat and impact to a structure. Evaluating the resistance against hazards that are not relevant for the area would be unnecessary and misdirected, while the assessment should prioritise and address the most relevant and probable events specific to the building location. This targeted approach ensures that resources and efforts are effectively allocated to mitigate the actual risks faced by the building. Therefore, resilience to extreme events is evaluated by first identifying the relevant scenarios and then considering the anticipated hazard linked to the lowest performance, in terms of reliability of the approach used for hazard characterisation and hazard resistant design.

An additional aspect of contextual diversity, taken into account by the self-assessment method, is related to the renovation of buildings with a historic or architectural value that has to be preserved and safeguarded. Typically, projects addressing listed buildings, require greater effort and higher costs. As one of the main goals of building retrofitting in the context of climate change mitigation is improving the energy efficiency and thermal performance of buildings, deep renovations are necessary. In the case of heritage buildings, such renovations require in-depth knowledge and thorough analysis alongside the significant workload and increased costs. These requirements stem from prohibitions on intervening on building envelopes, the necessity to preserve the original building materials and adopt reversible retrofit measures, as well as the inherent difficulty in changing ventilation methods, using renewable energy sources or complying with modern structural safety standards. Similar difficulties concern physical accessibility for people with limited mobility because in certain cases, introducing accessibility improvements may negatively affect the preservation of the original form of buildings or spaces. In the self-assessment method, an effort is made to reward projects that while ensuring the preservation of heritage value, they manage to promote NEB principles. This aspect is considered in the Beauty dimension through the assessment of improved preservation of cultural and natural heritage. Specifically, a project addressing listed building will be assessed against such indicators as Historical fabric preservation, Integrated heritage landscape conservation, and Improving preservation of cultural and natural heritage in renovated buildings.

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List of abbreviations and definitions

A	Acceptable performance class
B	Beauty dimension
BREEAM	Building Research Establishment Environmental Assessment Methodology
COM	Commission communication
D	Dimension
DEGURBA	Degree of Urbanisation
DGNB	German Sustainable Building Council (Deutsche Gesellschaft für Nachhaltiges Bauen)
E	Excellent performance class
FMI	Federal Ministry of the Interior and Community (Germany)
G	Good performance class
I	Inclusiveness dimension
KPI	Key Performance Indicator
L	Low performance class
LEED	Leadership in Energy and Environmental Design
M	Metric
LAU	Local Administrative Unit
NEB	New European Bauhaus
OMC	Open Method of Coordination group of EU Member State experts
PCS	Performance Class Score
S	Sustainability dimension
SFoC	Swiss Federal Office of Culture
SM	Sub-metric
UN-Habitat	United Nations Human Settlements Programme
w	weight

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Chapter 3: Sustainability

3 Sustainability

3.1 Introduction

The dimension of Sustainability within the New European Bauhaus (NEB) paradigm identifies the environmental and economic perspectives as two main drivers to promote a holistic approach for the design or renovation of buildings and living spaces that are not only ecologically responsible, but also financially viable in the long term. This approach encourages the development of innovative solutions that minimise environmental impacts, while also generating economic value, thus fostering a symbiotic relationship between ecological stewardship and economic prosperity.

The environmental perspective of the sustainability dimension needs to address issues related to energy, greenhouse gas (GHG) emissions, and other non-energy related environmental impacts from the built environment, as follows:

- *Energy* – The European Union (EU) building stock, including both the residential and service segments, constitutes the most energy demanding sector in the 27 European Union Member States (EU-27), reaching 391.2 million tonnes of oil equivalent (Mtoe) in 2021, corresponding to 44 % of the EU total final energy consumption (European Commission, 2023a; 2024). The use of fossil fuels for direct combustion represents 43 % of the final energy consumption in the EU buildings, followed by electricity at 29 % and renewables at 17 %. The operation of buildings is responsible for significant environmental impacts due to the indirect emissions associated with the generation of electricity, since 58 % of the final electricity consumption is used in EU buildings. The gross electricity generation in the EU-27 depends on over 37 % of fossil fuels (i.e. 20 % natural and manufactured gas, 15 % solid fuels and 2 % oil), 38 % renewables (i.e. 13 % wind, 13 % hydro, 6 % solar, 4 % solid biofuels, and 2 % biogases) and 25 % nuclear (European Commission, 2024).

  Accordingly, the 2024 recast Energy Performance of Buildings Directive (EPBD) (Directive, 2024) requires very high energy performance buildings with zero or minimum direct and indirect use of fossil fuels. Specifically, the minimum building code requirements across the EU-27 for new buildings and major renovations are the nearly zero-energy buildings (NZEBs) towards further enhanced zero-emission buildings requirements. NZEBs shall exhibit nearly-zero or very low energy demand that should be covered to a very significant extent by renewable energy sources (RES), combined heat and power (CHP) generation or efficient district heating and cooling, whereas zero-emission buildings require zero or a very low amount of energy and produce zero on-site carbon emissions from fossil fuels. The 2024 recast EPBD (Directive, 2024) set that each EU-27 Member State shall establish a trajectory for the progressive renovation of its residential building stock ensuring the reduction of the average primary energy use of residential buildings by at least 16 % by 2030 and at least 20-22 % by 2035, compared to 2020. Furthermore, Member States shall ensure that at least 55 % of the decrease in the average primary energy use is achieved through the renovation of the 43 % worst-performing residential buildings (Directive, 2024). New buildings will have to be solar-ready, being fit to host the installation of rooftop photovoltaic or solar thermal installations, thus leading solar energy systems to become part of minimum requirements for all new public and non-residential and residential buildings. For existing public and non-residential buildings, the installation of solar systems shall be gradually ensured by 2027-2030, depending on the useful floor area of buildings, if the installation is technically suitable, and economically and functionally feasible.

- *GHG emissions* – The GHG emissions associated with the building sector include direct emissions from onsite combustion for heating and indirect emissions from power plants to generate electricity using solid, liquid, and gas fossil fuels, as well as gas flaring. In 2021 the direct GHG emissions from fuel combustion in the building sector, including residential and non-residential (i.e. commercial/institutional) sectors amounted to 454.33 million tonnes of carbon dioxide equivalent ($MtCO_2eq$), corresponding to 17 % of the energy-related total GHG emissions in the EU-27 (European Commission, 2023a; 2024), mainly dominated by carbon dioxide (CO_2) emissions from fossil fuels (EEA, 2023). However, the largest key category for GHG emissions in the EU-27 is from public electricity and heat production, within the sector of energy industries, contributing to about 20 % of the total GHG emissions in 2021 (European Commission, 2024). In 2021 residential and non-residential (i.e. commercial/institutional) building sectors in the EU-27 accounted for 333.58 $MtCO_2eq$ and 120.74 $MtCO_2eq$ direct operational GHG emissions from onsite combustion, respectively. However, it is worth to also consider the indirect operational GHG emissions due to electricity consumption, as calculated according to Balaras et al. (2024): in 2021 indirect operational GHG emissions result into a value equal to 215.48 $MtCO_2eq$ and 200.98 $MtCO_2eq$ for the EU-27 residential and non-residential building sector, respectively. Considering the direct and indirect emissions collectively, the operation of buildings contributes to 24.5 % of the total GHG emissions in the EU-27. Accounting for the GHG emissions associated with the construction industry will also add approximatively another assumed 10 % from extraction, transportation, and manufacturing building products and materials, which is associated with the embodied GHG emissions. The recast EPBD (Directive, 2024) set a new minimum requirement for new buildings which shall be zero-emissions buildings across the EU-27 as of 1 January 2028 for buildings owned by public bodies, and as of 1 January 2030 for all other new buildings. Specifically, new buildings shall require zero or a very low amount of energy, producing zero on-site carbon emissions from fossil fuels and zero or a very low amount of operational greenhouse gas emissions, determined according to the Annexes of the recast EPBD (Directive, 2024). Furthermore, deep renovation should transform existing buildings into zero-emission buildings after 2030.

The EU transport sector is responsible for nearly a quarter of the EU total GHG emissions that has been increasing since 1990 (European Commission, 2023a). Projections indicate that domestic transport emissions will only drop below their 1990 level in 2029. Road transport exhibits the highest proportion of GHG emissions, reaching 73 % of the total amount of the EU GHG emissions due to transport, also including international aviation and international navigation, in 2022 (European Commission, 2024). The European Green Deal (COM, 2019) calls for a 90 % reduction in GHG emissions from transport to meet the overarching goal for the EU of being the first continent with a climate-neutral economy by 2050, while also working towards a zero-pollution ambition.

— *Other non-energy related environmental impacts* - Beyond energy consumption and GHG emissions, the built environment also generates significant impacts related to air, water, and raw materials.

Indoor air quality in buildings is very important as it can impact human health, since Europeans spend more than 90 % of their time inside buildings. Studies reveal that indoor air quality may directly threaten the occupants' health and, in some cases, may also be twice as polluting as outdoor air (European Commission, 2003). As a result, building occupants are exposed to hundreds of volatile components and some of them are toxic, mutagenic or carcinogenic. National regulations for indoor pollutants, such as carbon dioxide (CO_2), formaldehyde (CH_2O), particulate matter (PM), nitrogen dioxide (NO_2), carbon monoxide (CO), and radon (Rn) define acceptable levels in relation to human well-being inside buildings and building energy performance (Dimitropoulou et al., 2023).

Water is a vital natural resource, thus its management and consumption are considered major concerns of the environmental protection at EU level, according to the Water Framework Directive (Directive, 2000). The building sector is responsible for a significant pressure on this natural resource leading to a major concern for its handling, since about 21 % of all water abstracted in the EU is used for public supply, the majority of which is used in buildings (Donatello et al., 2021a). Furthermore, in the EU households the use of water from public supply averages around 40-50 m^3 per inhabitant (Eurostat, 2023a).

The built environment accounts for half of all extracted raw materials and produce vast quantities of construction and demolition waste (CDW), thus being responsible for over 35 % of all waste generated in the EU (COM, 2020a). A change of direction based on the increase of material efficiency has led the EU to promote circularity principles and design for deconstruction practices to recover reusable materials from demolished buildings, also avoiding GHG emissions due to the production of new materials. In addition low-carbon building materials and energy-efficient construction techniques play a pivotal role in reducing the carbon footprint of the construction sector. The ultimate goal of circular construction is to eliminate waste from the construction value chain and reduce the reliance of the construction sector on finite resources.

The economic perspective of sustainability for projects in line with the NEB initiative (COM, 2021a) should follow the three levels of ambition introduced in the Compass (European Commission, 2022): (*i*) to repurpose, (*ii*) to close the loop and (*iii*) to regenerate. The economic perspective of sustainability addresses two main aspects: (*i*) a more efficient use of scarce resources and the use of less money in a more effective way, and (*ii*) the investigation and collection of diverse potential sources of existing public funding and available private funding to support projects. Hence, projects that are consistent with the eligible criteria of existing funding and/or prospect innovative and integrated ways to collect private financing should be favoured, with the secondary effect of reducing the amount of public expense. Specifically, the growing interest of the private sector in sustainable finance, which relies on non-financial factors, i.e. environmental, social, and governance (ESG) criteria, should be used to advertise and offer coherent development opportunities. This approach becomes potentially more participatory, promoting the interaction across institutional levels and the involvement of private stakeholders that also include single citizens or local groups interested in crowdfunding campaigns.

In this context, three domains define the economic perspective of building and living space projects in line with the NEB concept:

- *Greening the public sector in terms of its economic involvement in the sustainability of the built environment* – Public investment in buildings and living spaces aims to transform places or the functions provided to the community, thus creating value for people. In this sense, 'greening of the public sector' aims to emphasise the role of public sector as a pioneer and demonstrator.
- *Greening the private and financial sector in terms of its economic involvement in the sustainability of the built environment* – The promotion of the NEB vision requires the private and financial sector to be as innovative and forward-thinking as the designers and architects of projects. The financial sector can play a pivotal role in materialising the NEB vision by developing specialised financial products, navigating the dynamic regulatory framework, embracing long-term investment strategies, leveraging technology, building capacities, engaging in international collaborations, and prioritising community engagement.
- *Promote circular economy* (CE) – Circular economy is an emerging approach to resource management focusing on the design of processes agenda and encouraging more upstream solutions and interventions towards a systemic change. CE is regenerative by design, built on the principles of eliminating waste and pollution, keeping products and materials in use, and regenerating natural systems. In 2015, the European Commission introduced its first circular economy action plan (COM, 2015), leading to the adoption of the new version of this action plan in 2020 (COM, 2020a) as one of the main blocks of the European Green Deal. The NEB initiative provides Europe with the opportunity to demonstrate the potential of the circular economy that moves from technicalities and resource economics to achieve a circular society, leading to adeep cultural resonance. CE leads to several advantages for the economy and its functions. Many economic benefits and opportunities due to CE are long-term and indirect and require significant investment. Hence, long-term benefits are a key-point to consider, as well as short-term incentives, to drive the change. In this context, policies that create more immediate financial incentives for businesses may facilitate the development of innovative new business models and enable the efficient flow of reused and recycled materials across global value chains. According to the United Nations Environmental Programme (UNEP), in 2050, the global economy will benefit by USD 2 trillion a year from more effective resource management (Ekins et al., 2017) since the cost of raw materials will decrease substantially while promoting employment and innovation. Although the attention for the circular economy is increasing, the extraction and prices of primary raw materials are still rising and the global circularity rate results into a steady decline, passing from only 9.1 % of all raw materials fully recycled in 2018 to 7.2 % in 2023 (CEF, 2024). A theoretical full circular economy corresponds to the recycling of 100 % of generated waste in secondary raw materials so that no new virgin raw materials are needed. However, this scenario can be achieved in a very long time, as it is still needed to develop effective methods to fully recycle materials that are currently used in products (Fellner et al., 2017).

3.2 Assessment targets to achieve

Sustainability concerns are addressed by assessing their status or progress towards nine targets related to both environmental and economic perspectives. The targets considered within the environmental perspective mainly refer to energy (e.g. direct operational energy demand, and use of renewables), greenhouse gas emissions due to operational-embodied energy and sustainable mobility, and non-energy related environmental impacts to air, water, and the use of materials along with construction and demolition-related waste. The targets reflected within the economic perspective regard the role of the economic involvement of the public sector, the private and financial sector, and the promotion of circular economy.

3.2.1 Minimise fossil fuel use

Energy efficiency first principle (Directive, 2023a) is the main guiding principle, complementing relevant EU objectives in sustainability, climate neutrality and green growth, becoming particularly significant in the construction sector to achieve buildings that exhibit a very low energy use from conventional or renewable energy sources. Hence, it is essential to minimise the primary energy consumption of buildings and maximise the use of renewable energy sources in line with the provisions of the recent recast EPBD (Directive, 2024).

In this context, the use of fossil fuels needs to be extensively reduced according to the following three objectives:

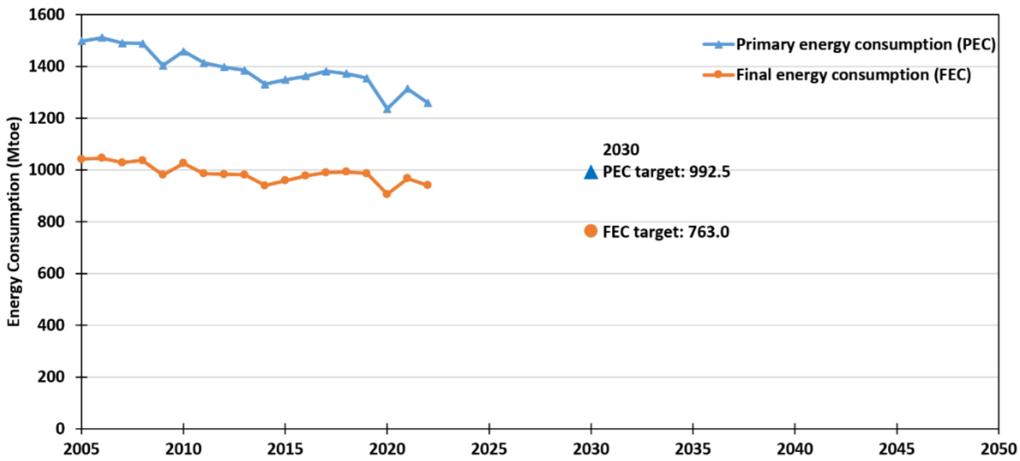
— Minimise the *primary energy demand* of buildings.

— Minimise the *electricity peak demand* for building operations, resulting into an essential goal considering the current electrification era of the building sector.

— Optimise the *smart readiness* (SR) capacity of buildings to sense, interpret, communicate, and actively respond in an efficient way to changing conditions related to the operation of technical building systems, the external environment (including energy grids) and the demand from building occupants. At a larger scale of a neighbourhood or a city, the smart readiness issues are addressed by smart meters to automatically monitor and adjust energy flows in response to changes in energy supply and demand, and possibly cost.

The **primary energy demand** is part of the definition of an NZEB, as introduced in the 2010 recast EPBD (Directive, 2010) and confirmed in the recent revised EPBD (Directive, 2024), to assess the energy performance of a building during its use stage. The energy performance of a building is also referred to as annual primary energy consumption, defined as any kind of extraction of energy products from natural sources to a usable form. The exploitable natural resources include coal, crude oil, natural gas, etc., while the transformation of energy from one form to another, such as electricity or heat generated by thermal power plants, is not included in the primary energy production. Energy and climate targets set in the EU policies and legislative instruments are commonly articulated around the concept of primary and final energy consumption and emissions. The commitment to improve energy efficiency by 20 % by 2020 and the new binding energy efficiency target of reducing the EU energy consumption of at least 11.7 % by 2030, compared to the 2020 EU reference scenario projections for 2030 (Directive, 2023a), represent examples in this direction, as the need to improve the EU energy efficiency is generally expressed in primary and final energy consumption. Indeed, this 2030 ambitious target translates into a EU primary energy consumption target of 992.5 Mtoe and a final energy consumption target of 763 Mtoe in 2030 (Figure 5), corresponding to a reduction of 40.5 % and 38 % of primary and final energy consumption, respectively (compared to the 2007 EU reference scenario projections for 2030). The construction and renovation of buildings are recognised as some of the sectors with the greatest potential for energy savings, thereby using energy more efficiently, thus the EU established the requirement of NZEBs since 2020 towards zero-emissions buildings starting from 2028-2030 (Directive, 2024). However, the NZEB and zero-emission building requirements do not usually apply to the following categories of buildings: (*i*) buildings officially protected as part of a designated environment or because of their special architectural or historical merit, (*ii*) buildings used as places of worship and for religious activities, (*iii*) temporary buildings with a time of use of two years or less, (*iv*) residential buildings which are used or intended to be used for either less than four months of the year, (*v*) stand-alone buildings with a total useful floor area of less than 50 m^2 and (*vi*) buildings owned by the armed forces or central government and serving national defence purposes.

Figure 5. Primary and final energy consumption from 2005 to 2022 in EU-27.



Source: Adapted from EEA, 2024a; data from Eurostat, 2023b.

The **electricity peak demand** is emerging to a major issue in the era of building electrification and represents the maximum amount of electricity demand required for building operation on a yearly basis. Advanced measurement technologies, demand response and smart grids facilitate building monitoring to manage peak demand. This contributes to grid stability and reduces environmental impacts by decreasing reliance on fossil fuels during peak periods. Energy-efficient buildings, demand response programs, energy storage systems, and the integration of renewable energies are just some of the strategies used to mitigate peak demand in buildings. The use of automation systems, occupant education, time-based scheduling, and the adoption of energy-efficient lighting and electrical appliances further contribute to the electricity peak demand reduction, leading to lower energy costs and contributing to greater sustainability and a more comfortable indoor environment.

The **smart readiness** of a building refers to its ability to use information technologies and electronic systems to adapt the operation of buildings to the needs of the occupants and the energy grid, as well as to improve the overall in-use energy performance of buildings, thus achieving a more energy-efficient, environmentally friendly, healthy, and comfortable indoor, in line with the recent EPBD recast (Directive, 2024). Smart readiness raises awareness of the benefits of smarter building technologies and functionalities and make their added value more tangible for building users, owners, tenants, and smart service providers. It supports technology innovation in the building sector and creates an incentive for the integration of cutting-edge smart technologies in buildings.

At neighbourhood/urban scale, according to the standard ISO 37122 (ISO, 2019), an integral part of smart cities is the use of smart energy meters that can optimise energy consumption, decrease GHG emissions, and help people save money on their energy bills.

3.2.2 Use of sustainable energy

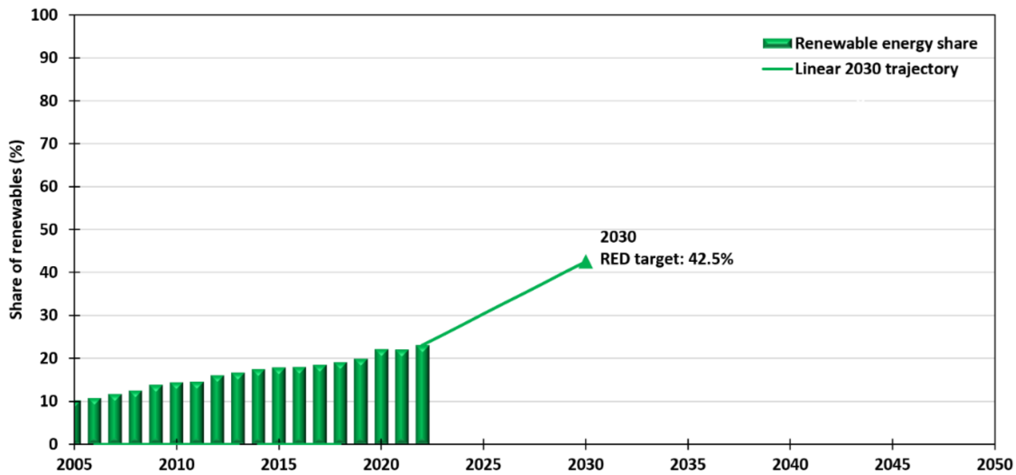
Once a building has achieved a high energy performance with low energy demand, the next target is to maximise the use of sustainable energy, according to the following two objectives:

— Maximise the *share of renewables* for thermal and electrical energy uses.

— Integrate *energy storage* systems to balance the variability of renewable energy sources.

A key element in the era of decarbonisation is the electrification of end-use sectors, including the building sector, with green electricity, which facilitates the transition to energy systems based on **renewable sources**. This mandates coherent efforts to simultaneously transform various elements of the energy system, e.g. increasing energy efficiency, decarbonising power generation with renewables, handling high shares of intermittent renewable electricity sources, with demand-side load management and energy storage. The share of the EU gross final energy consumption from renewable sources averaged 23 % in 2022, thus nearly doubling the share achieved in 2008 (Eurostat, 2023c). The revised Renewable Energy Directive (RED) (Directive, 2023b) set a new binding EU-wide renewable energy share target of at least 42.5 % in the EU gross final energy consumption by 2030 (Figure 6), with the aspiration to increase it to 45 %. However, it will be necessary to double the recent deployment rates of renewables and aim for a deep energy system transformation to meet this ambitious target.

Figure 6. Renewable energy share as a percentage of the EU-27 gross final energy consumption from 2005 to 2022 and progress towards the EU target by 2030.



Source: Adapted from EEA, 2024b; data from Eurostat, 2023c.

The building sector can contribute to this goal by promoting the integration of the production and use of renewable energy in buildings. The share of renewable energy related to the final total delivered energy demand for building operations quantifies the proportion of renewable energy used on an annual basis by a building in relation to the total delivered energy demand for the end-use energy services, i.e. heating, cooling, and dehumidification, ventilation, and humidification; hot water; and lighting (optional for residential buildings). This quantifies the percentage of the relative improvement of the share of renewable energy for the operation of a building against a baseline reference. The revised RED (Directive, 2023b) sets an indicative target of at least a 49 % renewable energy share in buildings by 2030. As a result, the use of renewables for heating and cooling in buildings shall gradually increase, targeting an annual increase of the renewable energy share of at least 0.8 percentage points at national level until 2026 and 1.1 percentage points from 2026 to2030, compared to the share of renewable energy in the heating and cooling sector in 2020.

Energy storage is a crucial means to capture and store energy from renewable sources (e.g. wind, solar, or hydroelectric power) to be used later, enhancing the flexibility, stability, and reliability of an energy system, also considering the increasing share of renewable energy sources in European electricity grids. Indeed, the production of renewable energy sources is inherently variable, as it is heavily dependent from environment conditions, which fluctuate daily and seasonally. Hence, the energy storage can effectively contribute as one of the technologies that can reduce the flexibility requirements (FRs) of an energy system. FRs represent the energy fluctuation in relation to the average in a specific period, thereby indicating the need for technical solutions to address energy system flexibility. Three different approaches may be considered for energy storage in the EU, with specific data collected in a dedicated database of the European energy storage technologies and facilities (European Commission, 2020a), as follows:

- 'Front-of-the-meter facilities', including energy storage facilities in the EU, operational or in project, connected to the generation and the transmission grid.
- 'Behind-the-meter energy storage', which refer to installed capacity per country of all energy storage systems in the residential, commercial and industrial infrastructure.
- Energy storage technologies, classified in five main categories (i.e. mechanical, electrochemical, electrical, chemical, and thermal) depending on the type of energy acting as a reservoir.

The energy storage technologies enable the storage of energy surplus during low-demand periods and provide it during high-demand periods, allowing the efficient management of supply and demand fluctuations across various timescales and facilitating grid stability. Different characteristics and capabilities offered by energy storage technologies based on power capacity and discharge time are reported in EASE (2022). Energy storage can be electrical, when input and output are electricity (Power-to-X-to-Power), or thermal when input and output are thermal energy, among various energy storage technologies. Electrical energy can be stored in the form of chemicals or as thermal energy (Power-to-X).

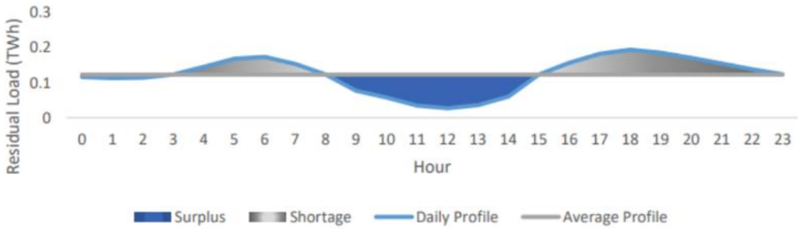
Energy storage solutions can be deployed at various spatial scales, from individual buildings to entire urban areas. At building scale, energy storage systems help to optimise the energy use, ensure a stable power supply, and are a critical enabler for increased reliance on renewables. Specifically, three typologies of energy storage systems can be considered to achieve these goals, as follows:

- Passive short-term storage, which uses the building components for thermal energy storage in the form of sensible or latent heat storage.
- Active short-term storage, which includes water tanks, ice storages, batteries (electrochemical), flywheels (mechanical), super-capacitors (electrochemical), compressed air storage (mechanical), hydrogen (chemical).
- Active seasonal storage, which refers to underground thermal energy storage or thermochemical.

At neighbourhood and urban scale, energy storage systems can enhance grid resilience, balance fluctuating energy demands, and support electric transportation infrastructure.

The increase in the share of variable renewable energy sources leads to constantly changing residual load dynamics, necessitating flexibility solutions across various timeframes. The storage solutions must align with specific timescales, ranging from short-term, like batteries offering flexibility within hours, to long-term, such as seasonal hydro storage providing flexibility over months at a city or regional scale. The flexibility requirements can be estimated based on the residual load curve, which is derived by subtracting the variable renewable supply from the power demand. The 2030 residual load curve in terawatt hours (TWh) in the EU (Figure 7) is expected to have two peaks, one in the morning and another in the evening, which correspond to periods of higher electricity demand. There is also a noticeable decrease during midday when solar PV generation reduces the remaining demand. The residual load curve provides insight into the portion of the electricity demand that can be covered by flexible technologies.

Figure 7. Flexibility requirements based on daily EU residual curve in 2030.



Source: Koolen et al., 2023.

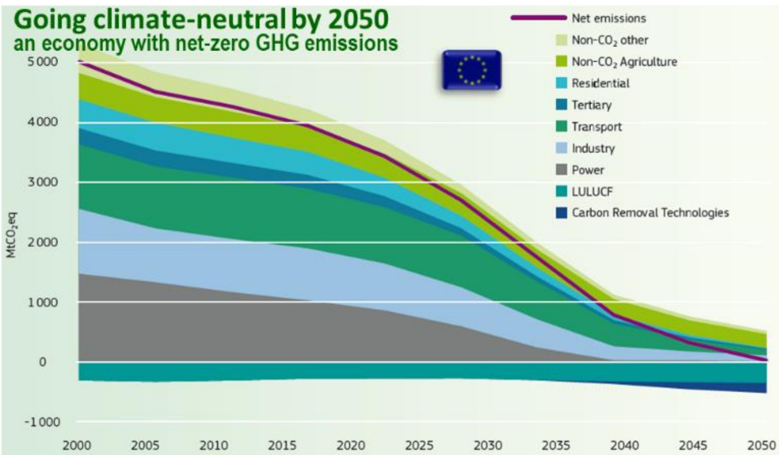
3.2.3 Minimise greenhouse gas emissions

The target intents to minimise the whole life cycle GHG emissions that constitutes a pillar of EU policies to control the impacts of climate change. Accordingly, the target aims to achieve the two following objectives:

- Minimise the *operational GHG emissions* by eliminating onsite combustion of fossil fuels.
- Minimise the *embodied GHG emissions* for the manufacturing of building construction materials, products, components and systems.

Operational GHG emissions are mainly generated by the energy use of the building-integrated technical systems, such as space heating, domestic hot water (DHW), cooling, ventilation, and lighting during the usephase of the life cycle of a building. The reduction of the operational GHG emissions of buildings towards zero emissions buildings is a priority to reach the EU climate-neutrality goal by 2050, in line with the GHG emission trajectory in a scenario limiting the global warming to 1.5°C above the pre-industrial levels (Figure 8), according to the Paris Agreement objectives (UN, 2015a).

Figure 8. Trajectory for GHG emission reduction in the EU-27 in all sectors for climate-neutrality by 2050.



Source: European Commission, 2019.

Embodied GHG emissions of a building are generated in relation to manufacturing and processing construction products/materials used throughout the whole life cycle of a building, from “cradle” (i.e. the extraction of the raw materials for the production of construction products/materials) to “grave” (i.e. the deconstruction of the building at its end-of-life stage, along with the disposal and potential recycle/re-use of the building materials and components).

At neighbourhood and urban scale, the natural photosynthesis of urban vegetation is identified as an effective approach to capture and store carbon on site to reduce CO_2 emissions, although he potential of natural photosynthesis to uptake and store carbon varies significantly depending on the plant typology (e.g. trees, bushes or herbaceous), growth conditions, climate, and maintenance methods (Kuittinen et al., 2021). In urban areas, it was estimated that the annual natural sequestration potentials from trees range from 5.9 tonnes of carbon dioxide per hectare per year (tCO_2/ha/y) in Mexico to 10.3 tCO_2/ha/y in USA (Shafique et al., 2020). Green roofs primarily reduce the energy demand of buildings helping to decrease CO_2 emissions indirectly. However, they also exploit the natural photosynthesis approach exhibiting a carbon sequestration potential that varies from 0.3 kilograms of carbon dioxide per square meter per year ($kgCO_2/m^2/y$) to 7.1 $kgCO_2/m^2/y$, depending on conditions and variables mainly related to plant types and soil layers (Shafique et al., 2020; Kuittinen et al., 2021). Nevertheless, most of this sequestered carbon is stored only for a short time, as herbaceous plants decompose naturally over growing seasons. Carbon also accumulates in soils due to organic processes, thus soils result into the largest terrestrial carbon stock. The potential of soil to store carbon varies considerably depending on climate, soil type, vegetation, erosion, microbial activity, pollution, and other factors. In urban areas, the amount of carbon stored in soils ranges from 213 to 741 tCO_2/ha (Kuittinen et al., 2021).

3.2.4 Sustainable mobility

The promotion of the sustainable mobility is a key-aspect of the European Green Deal (COM, 2019) to minimise the GHG emissions from transportation. Specifically, the decarbonisation of the transport sector depends on the implementation of three pillars of actions, according to the Sustainable and Smart Mobility Strategy (COM, 2020b): (*i*) make all transport modes more sustainable, (*ii*) make sustainable alternatives widely available in a multimodal transport system, and (*iii*) put in place the right incentives to drive the transition. These actions are essential to shift to zero-emission mobility, implying decisive measures concerning (*i*) the need to reduce the current dependence on fossil fuels by replacing existing fleets with low- and zero-emission vehicles, i.e. electric vehicles (EVs), also named as e-vehicles, while boosting the use of green electricity and using low-carbon fuels, (*ii*) the effort to shift more activities towards more sustainable transport modes (e.g. public transportation), and other alternative active mobility modes (e.g. use of bicycles).

In this context, the building sector plays an important role in terms of necessary infrastructure for electrical recharging and cycling promotion (Directive, 2024), thus the assessment target aims to enhance the sustainable mobility, which can be achieved through two main efforts:

— Foster *electric mobility* (i.e. e-mobility), facilitating the growth of electric vehicles in urban areas by providing the necessary infrastructure for recharging EVs at both building and neighbourhood/urban scale (e.g. public recharging points for EVs).

— Encourage *alternative active mobility*, e.g. through the use of bicycles, by providing the necessary infrastructure at both building (e.g. bicycle parking spaces) and neighbourhood/urban scale. Regarding the neighbourhood/urban scale, infrastructure for bicycle paths and lanes should be ensured, while main emphasis is also placed on public transportation systems.

E-mobility represents another facet of the electrification era. Electric vehicles are powered by electricity from batteries. Combined with an increased share of renewable electricity production, EVs emit fewer GHG and tailpipe pollutants, compared to conventional vehicles. However, electric vehicles exhibit a limited motor and battery capacity that enables shorter-distance travels depending on the EV range. A regular and convenient access to battery recharging stations is needed to overcome this inherent drawback of EVs, thus the availability of parking facilities for recharging EVs becomes essential at both building and urban scale for an effective use of EVs. According to the EPBD recast (Directive, 2024), buildings shall contribute to the development of the necessary infrastructure for sustainable mobility. Specifically, the installation of recharging points, and pre-cabling or ducting need to be ensured for new and majorly renovated residential and non-residential buildings in case a car park is located inside the new/renovated building, or it is physically adjacent to the new/renovated building. The use of smart charging and bi-directional charging is recommended to enable the energy system integration of buildings. Bidirectional charging, i.e. vehicle-to-grid (V2G) or vehicle-to-home (V2H), further supports the penetration of renewable electricity by electric vehicle fleets in transport and the electricity system in general. Furthermore, the bidirectional charging is instrumental to peak shaving, thus lowering the need for power supply at peak hours and, hence, the overall system costs. Similar considerations about the need of an adequate recharging infrastructure to support e-mobility also emerge at neighbourhood and urban scale. Public and urban-wide recharging points are important not only to ensure the use of EVs, but also to provide the supply of green and low polluting electricity, contributing to both less urban pollution from GHG emissions and citizens' wellbeing.

A shift to the **alternative active mobility**, such as cycling, can significantly reduce GHG emissions from transport. However, the lack of bicycle parking spaces in residential and non-residential buildings is a barrier to the uptake of cycling, also discouraging the use of bicycles (Directive, 2024). Hence, EU Member States shall ensure the provision of a minimum number of bicycle parking spaces for new and majorly renovated residential and non-residential buildings. Furthermore, the increase in the use of bicycles depends on the decisive factor to provide an adequate network of bicycle lanes and paths at neighbourhood and urban scale. A transportation system that is conducive to cycling can reap many benefits in terms of reduced traffic congestion and improved quality of life.

Public transportation systems are generally more energy-efficient and generate lower GHG emissions per passenger mile compared to private conventional cars. This helps the mitigation of climate change by reducing the overall carbon footprint of transportation. Hence, at neighbourhood and urban scale, it is essential to consider various aspects of the public transportation network concerning its extent, usage, and accessibility of the residents to boost a high-quality and multimodal transport system which takes advantage of the combination of the strengths of the different modes, such as convenience, speed, cost, reliability, predictability.

3.2.5 Non-energy related environmental impacts: air and water

The target aims to reduce the environmental impacts to air and water through two main objectives:

- Improve *indoor air quality* and secure the well-being of building occupants.
- Minimise *water use* in buildings and surface permeability in urban areas to preserve water reservoirs.

Indoor air quality can affect human health and well-being of building occupants, as it relates to sick building syndrome and impacts indoor environmental quality, thus the need to reduce the indoor air pollution is at the EU forefront awareness. Volatile organic compounds (VOCs) emitting from construction products are an important source of indoor air pollution. However, a common regulation in the EU concerning the health-related assessment of VOC emissions from construction products still lacks, although the EU regulation on construction products, (Regulation, 2011) requires that VOC emissions must not pose any risk to the health of building users. However, the same regulation does not implement any health requirement. Accordingly, the harmonised European standards defining relevant parameters for the product performance declaration do not address VOC emissions. Hence, few EU countries, such as Germany, France, have established national requirements for VOC emissions from construction products, while the EU proceeds with the ongoing progress of a harmonised approach to communicate construction product emissions in terms of VOC classes (Scutaru and Witterseh, 2020). Outdoor air quality can impact the building indoor conditions and the quality of life in cities. The EU has also recognised the importance of this issue, thus placing emphasis on ambient air quality standards, reduction of air pollution emissions, and emissions standards for key sources of pollution. The EU zero pollution action plan (COM, 2021b) sets the '2030 target' to reduce the health impacts of air pollution (the number of premature deaths) by more than 55 % compared to the 2005 levels and the '2050 vision' to reduce air, water and soil pollution to levels no longer considered harmful to health. European standards include reference methods for sampling and measuring the following indoor pollutants: PM_{10} and $PM_{2.5}$ in ambient air according to EN 12341 (CEN, 2023), ozone according to EN 14625 (CEN, 2012a), sulphur dioxide according to EN 14212 (CEN, 2012b), and nitrogen dioxide according to EN 14211 (CEN, 2012c). Moreover, the Copernicus Atmosphere Monitoring Service (CAMS) Air Control Toolbox[1] provides practical European air quality forecasts, like the air quality models that are also available from the Support Center for Regulatory Atmospheric Modeling of the United States Environmental Protection Agency (US EPA)[2]. Accordingly, it is important to minimise the potential intake of outdoor particulate and gaseous pollutants to the ventilation system. Potential solutions to minimise the intake of outdoor air pollutants (e.g. fine dust and benzene) could be to place the ground level air intakes on the side of the building that is exposed to the carpark, thus avoiding the building sides exposed to the main road, and to provide the sheltering of ground-level air intakes by a row of densely planted trees. The indoor generation of air pollutants (e.g. off-gassing of VOCs from fit out materials or insulation) can be minimised by selecting and using low-emission materials. Each individual VOC has its own potential toxicity upon exposure to humans. The building ventilation strategy with clean outdoor air can also play an important role to freshen up the indoor air, thus reducing indoor air pollution. A hybrid ventilation system can be effective where natural ventilation provides sufficient air change rates for emissions from building components and occupants during low occupancy periods, while mechanical ventilation can be used during periods of normal and high occupancy. The mechanical ventilation system should be able to provide a safety margin against the build-up of VOCs from

[1] CAMS Air Control Toolbox: https://policy.atmosphere.copernicus.eu/act.php
[2] US EPA, Support Center for Regulatory Atmospheric Modeling: https://www.epa.gov/scram

fit-out materials/furnishings and against the remaining of bio-effluents in indoor air. Localised ventilation strategies can be used to control point sources in areas of the building (e.g. cooking areas, bathrooms, meeting rooms with occasionally high occupancy) and consider a separate exhaust, for defined time periods, with a high specific ventilation rate.

Water availability is unevenly distributed in Europe, despite the relevant abundance of freshwater resources, thus leading to major differences in terms of water stress for the European population over seasons and regions. Although the overall use of water resources can be considered sustainable in the long-term in most of Europe, specific regions, particularly in southern Europe, may face serious challenges related to water scarcity and seasonal water shortages. Hence, a more efficient use of water will also reduce pressure on freshwater resources, especially in river basins that experience continual or seasonal water scarcity. In areas where the desalination is necessary for water supply (especially in southern Europe), the cost and environmental impacts for an efficient water use are significantly higher due to the larger amount of energy needed to treat the water. An average of 144 litres of freshwater per person per day is supplied for the European household consumption, which is almost three times the water requirements for basic human needs (EEA, 2018). Reducing water consumption at building scale will lessen the environmental impacts of delivering water to the point of demand (i.e. from water abstraction, treatment and pumping through the distribution network), thus sustaining a healthy natural environment, while meeting human needs (Directive, 2000). In the case of domestic hot water, better efficiency also leads to significant energy savings for consumers. The trend towards larger urban populations is placing even more pressure on water supply at urban scale. Furthermore, surface permeability should be ensured in urban areas, as it is an important environmental characteristic for the natural water cycle. However, the extent of impermeable surfaces in urban areas is continually increasing, as cities expand due to the construction of buildings, roads, streets, parking lots, etc. to rapidly adjust to population growth. As a result, surface imperviousness increases with the consequent increase of the volume and velocity of surface runoff and the reduction of water infiltration, which can also lead to floodings. In this context, the EU soil strategy for 2030 (COM, 2021c) provides a framework and relevant guidelines to mitigate, limit or restore the sealed soil areas.

3.2.6 Non-energy related environmental impacts: construction materials

The EU is committed to circular economy, emphasising resource efficiency and waste reduction to minimise the use of raw materials, energy, water, also lessening GHG emissions. In this context, the target addresses environmental impacts related to construction materials through the following objective:

— Minimise *waste* from building construction and demolition activities.

The **construction and demolition waste (CDW)** management in the EU is closely intertwined with the overarching goal of the decarbonisation strategy. Over 2 tonnes of CDW are generated for each European citizen on an annual basis, accumulating about 500 million and 1 billion tonnes. In 2020, CDW in the EU accounted for over 800 million tonnes (Eurostat, 2023d). As a result, CDW accounts for more than a third (i.e. 35 %) of all waste generated in the EU (COM, 2020a). Based on these figures, it is not surprising that CDW is a priority waste stream under the Waste Framework Directive (Directive, 2008) aiming to increase the preparing for re-use, recycling and recovery of non-hazardous CDW to a minimum of 70 % (by weight) by 2020, promote selective demolition, establish sorting systems and reduce waste generation. In this context, sustainable construction practices that prioritise the reduction of CDW through recycling and reuse should be applied to both the new construction and the renovation of buildings. In fact, renovation works also generate CDW since the intervention may also involve the structural alteration of buildings, replacement of main services or finishes, while at the same time including associated redecoration or restoration works.

3.2.7 The role of the economic involvement of the public sector

The **public sector** investments in buildings or living spaces often aim to transform places or enhance the functions provided to the community, thus supporting the economic development, stimulating economic growth, creating jobs, and attracting more investment to the transformation project area. In this context, the assessment of the use and performance of potential public investments become particularly relevant for a project in line with the NEB vision.

Traditionally, evaluation frameworks, such as cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA), have been used to assess the viability of a public investment. However, in recent times, the social return on investment (SROI) methodology has been promoted as a more holistic approach to demonstrating the social, economic, and environmental values, expressed in monetary terms, to provide a comprehensive view of the benefits to people and nature created by the investment cost. Furthermore, economic activities aligned with environmental policies have been encouraged through the introduction of the 'Do No Significant Harm' (DNSH)-principle, which aims to avoid investments or reforms that would cause significant harm to the six environmental objectives defined in the EU Sustainable Investment Regulation (Regulation, 2020), thus achieving environmentally-sensitive management of public finance.

The Cost-Benefits Analysis is an analytical tool that assesses the variation in social welfare resulting from an investment decision (usually related to land or infrastructure development) and, consequently, its contribution to achieving the objectives of a project or an overarching policy. A CBA relies on the assumption of allocating resources for a project until the marginal social benefit equals the marginal social cost. Hence, a project or a policy can be considered valid from a societal point of view, if the benefits generated exceed the costs. A CBA aims to facilitate a more efficient allocation of resources by demonstrating the convenience of a particular intervention for society compared to other possible ones. The CBA evaluates the purely financial convenience of a project, assesses the necessary financial backing, and identifies any participation in the backing by the users. The financial performance evaluated through a CBA relies on the following project investment criteria, which measure the profitability of a project:

— The net present value (NPV) is given by the difference between discounted benefits (B) and costs (C) at a given discount rate (r), over the project lifetime (T) in years, according to Equation (4).

$$NPV = \sum_{i=0}^{T} \frac{B_i - C_i}{(1+r)^i} = B_0 - C_0 + \frac{B_1 - C_1}{(1+r)^1} + \frac{B_2 - C_2}{(1+r)^2} + \cdots + \frac{B_T - C_T}{(1+r)^T} \quad (4)$$

  If the NPV is positive, the social benefits are higher than the social costs. If the alternative is the status quo with zero costs and benefits, a positive NPV indicates that the project can be implemented. By comparing different options for a project, having the same investmentsize, the solution with a higher NPV is preferred.

— The internal rate of return (IRR) is the discount rate that would make the current value of a project equal to zero (NPV = 0), namely the discount rate that allows the value of the initial investment to be recovered at the time (T). Based on this, a project is eligible, if it exceeds the opportunity cost of the investment. The reference is usually taken as a non-risky investment (e.g. bank deposit). By comparing different projects, the option with a higher IRR is preferred.

— The cost-benefit ratio (B/C) is given by the ratio between the sum of the benefits and the sum of the costs. The ratio must be greater than one (i.e. B/C > 1) to consider a project eligible. The ratio between the sum of the benefits and the sum of the costs must preferably be carried out by considering discounted values.

— The discounted payback period (DPBP) is a more accurate version of the simple payback period. The latter measures the amount of time (expressed in years) required to fully recover the initial cost of a project from the net annual cash inflows coming from the profits of the project implementation, without accounting for the time value of money. Indeed, the calculation of the simple payback period does not include the discount rate, whereas the DPBP takes into account the cumulative annual discounted cash inflows to equal the amount of the initial investment. The shorter the payback period, the more cost-effective the project is. However, either the simple or the discounted payback period is more relevant in the private sector than in the public sector.

It is possible that a project delivers a positive economic return in terms of social well-being, but this result is a loss from a purely financial point of view due to fragmented financial indicators that do not represent the overall economic value of the project. However, the social benefits generated can make the project worthwhile. As example, the realisation of a green area in a district has certainly a negative economic return since the costs of construction and management are not covered by any monetary revenue from users. However, the social benefits to the local community are relevant. In that case, integrative assessment frameworks, such as SROI, should be considered.

The Cost-Effectiveness Analysis is a tool for evaluating public projects or policies, particularly applied in the sectors of health, road safety, national defence, or energy efficiency. CEA identifies the most efficient way in economic terms to achieve a given objective. It is generally preferred to a CBA by non-economically trained analysts (e.g. engineers, doctors, etc.), who may be less inclined to accept the controversy of monetising the benefits of "intangible" goods, such as human life, time, health, or environmental services, which a CBA requires. The CEA is also applied by economists who did not recognise the underlying social welfare approach of a CBA.

In the CEA only the direct costs invested in the project are considered. At the same time, the effectiveness is measured through a single outcome, which stands as the main expected impact of the intervention and is used to compare costs and the impact of alternatives within the same domain. It does not evaluate the monetary value of the outcomes as they are reported as natural units (e.g. lives saved, or cases averted). Similarly to the CBA, stakeholders are not involved in the process; the evaluator defines the main objective of the intervention and its impact. A CEA can be applied as an ex-ante evaluation to steer the decision-making process or as an ex-post evaluation of an intervention. When selecting alternatives, the intervention with a higher cost-effectiveness ratio is better. If the project outcome cannot be defined as a priority outcome or if homogeneous and quantifiable units cannot be determined, cost-effectiveness analysis should be avoided. The typical evaluation criterium of a CEA is the incremental cost-effectiveness ratio, defined as the ratio of change in costs to the change in impacts. A classic and interesting example of a cost-effectiveness analysis is the marginal abatement cost curves, used to visualise the abatement cost and the abatement potential of CO_2 emissions.

The social return on investment methodology is a framework for measuring and accounting for a much broader concept of value created by a project/activity (Nicholls et al., 2012; Banke-Thomas et al., 2015; Cordes, 2017). SROI seeks to prevent inequality and environmental degradation, and improve well-being by incorporating social, environmental, and economic costs and benefits to indicate how the change due to a project/activity is being created. SROI was initially developed and used to evaluate social investments, such as programs for combating drug or alcohol abuse, supporting job search, and reducing the need for social assistance and empowerment. Recently, it has also begun to be used in evaluating complex urban programs, where activities in the built environment interpenetrate with those related to service delivery (Watson and Whitley, 2017). A SROI analysis may be carried out in two different forms: (*i*) as a 'SROI forecast', thus being an ex-ante evaluation which predicts the extent of the social value of a change that will be created if the project/program meets its intended outcomes, and/or (*ii*) as an 'evaluative SROI', which is an ex-post evaluation performed retrospectively and based on actual outcomes that have already taken place. Although the SROI methodology can be categorised as a form of cost-benefit analysis, a crucial distinction between a CBA and an SROI analysis regards the evaluation object. Specifically, a CBA takes as main evaluation object the outputs of the intervention (e.g. the physical, digital or natural infrastructure provided to a city against its cost). At the same time, a SROI analysis focuses on welfare changes experienced by stakeholders in being involved in a project/program and benefitting from its result (e.g. the outcomes that the existence of the physical, digital or natural infrastructure or the participation to its implementation during the co-design process delivers to a specific group of people, regardless its role in the process). Outputs are obvious in CBA and SROI, while outcomes in SROI should be defined by the analyst interacting with stakeholders. The general performance indicator of SROI is the ratio of the social return gained (B) translated into a monetary value to the initial investment (C), i.e. B/C. Methods and techniques for translating impacts into monetary values may be similar to the ones used in a CBA for non-market values. A further crucial practical consideration is the staff time and effort required to undertake a CBA or SROI analysis. Implementing an SROI analysis is relatively feasible when an organisation collects information on program outcomes, cost, and revenue.

The suitability of the evaluation frameworks and tools above to assess public investments for buildings, living spaces, infrastructures, and building services is summarised in Table 2.

Table 2. Evaluation frameworks and tools for public investments.

Evaluation tools	**Buildings**	**Living Spaces**	**Infrastructures**	**Building services**
CBA		✓[1]	✓[1]	
CEA		✓[1]	✓[1]	✓[1]
SROI	✓[2]	✓[1]	✓[3]	✓[1]
DNSH	✓[4]	✓[4]	✓[4]	

[1] Suitable for evaluation.
[2] Suitable for evaluation when there is a combination of tangible ('hard investment', such as infrastructure, construction, etc.) and intangible ('soft investment', such as human life, time, health or environmental services, etc.) goods or services for people.
[3] Suitable for evaluation but not frequently used.
[4] Suitable for evaluation only for 'hard investment', mandatory for interventions financed by National Recovery and Resilience Plans.

Source: JRC.

Beyond the public investments for which future benefits are inherently expected, public fundings may also reveal particularly relevant for projects in line with the NEB vison, mainly to support local transformations. In this context, the performance of fundings also needs to be evaluated and the funding accountability should be enhanced, so it is crucial to clearly present funding mechanisms and their figures in the design phase of a project. This includes detailing the financial resources to support a project and their contribution to the economic development. By outlining funding sources and amounts, stakeholders can better understand the impact of an investment on local economies.

3.2.8 The role of the economic involvement of the private and finance sector

A key-aspect to support NEB projects relies on the development of specialised financial products and investments from the private sector. Traditional financial instruments may not adequately address the unique characteristics of projects aligned with the NEB vision, which generally blends aspects of sustainable technologies, functionality and aesthetics, and community engagement. This drawback can be overcome by considering new financial instruments in the form of debt (i.e. bonds and loans) or equity (i.e. funds) for sustainable growth-oriented projects, such as green loans, sustainability bonds, and impact investment funds, to be specifically designed for projects compliant with the NEB vision. These financial products would ensure the flow of capital towards NEB initiatives and reinforce the growing importance of *sustainable finance*, which is generally referred to as the process of integrating ESG criteria into investment decisions within the private sector (Boffo and Patalano, 2020; Cauthorn et al., 2023). Particular attention within the sustainable finance is drawn up to the environmental subset of the sustainable development in line with the European Green Deal objectives, leading to the *environmental* (or *green*) *finance* that concerns private financing only focused on ecological issues aimed at optimising environmental benefits or reducing and/or adapting to environmental risks, as a complement to public investment (Miroshnichenko and Mostovaya, 2019; Maltais and Nykvist, 2020). Specifically, green finance supports the transition to a climate-resilient economy through the two following subsets: (*i*) the *carbon finance* enabling climate-change mitigation actions, especially related to the GHG emissions reduction, and (*ii*) the *climate finance* for climate-change adaptation efforts towards promoting the climate resilience of infrastructure. Applications of carbon finance include low carbon projects, such as projects for the reduction of GHG emissions from deforestation and forest degradation (REDD+), whereas applications of climate finance regard clean energy and energy efficiency projects, as well as climate change adaptation projects, such as building flood defences to warming waters. Beyond climate-related issues, green finance also channels capital into projects addressing other environmental issues (e.g. related to air, soil, water, etc.) (Gilchrist et al., 2021). The involvement of private sector capital in climate finance should be enhanced, with a particular focus on innovative financial tools. In private climate finance, various financial tools are utilised, including environmental, social, and governance funds with a focus on climate considerations, private equity investments, and venture capital injections into climate-related businesses. Additionally, shareholder engagement is employed to encourage companies to make environmentally responsible investment decisions. An increasing number of institutional investors, investment funds, and credit institutions have begun to address climate change and sustainability. Various financial instruments have seen an increasing use in the climate finance in recent years. This trend has incentivised financial institutions from the private sector to explore climate-related offerings and collaborate with public-sector entities and multilateral development banks (MDBs) to create joint initiatives and partnerships (Mendez and Houghton, 2020). Major global investment funds can initiate investments in climate financial products within emerging markets and developing economies (EMDEs) by allocating a portion of their capital and diversifying their risk. These funds can collaborate with MDBs and national public sector organisations by dedicating a portion of their portfolio to climate-focused EMDE products and projects, aligning with their climate commitments and the preferences of their investors. An overview of the predominat new financial instruments within the various facets of sustainable finance, along with their main application to relevant projects, are reported by finance category in Table 3.

Table 3. Financial instruments within the sustainable finance.

Financing tool	Definition	Application	References
Climate and green finance			
Climate bonds	Fixed-income financial instruments that are linked with climate change solutions. They are issued to raise finance for climate change solutions for mitigation- or adaptation-related projects.	Climate change mitigation projects mainly related to GHG emissions reduction, such as clean energy and energy efficiency projects. Climate change adaptation projects, such as building flood defences to warming waters.	Lucchetta, 2023
Green bonds	Any type of bond instrument where the proceeds are exclusively applied to the finance or re finance of projects with clear environmental benefits (some projects may also be eligible for a 'green' designation).	Green projects, such as renewable energy, energy efficiency, pollution prevention and control, terrestrial and aquatic biodiversity conservation, clean transportation, sustainable water and astewater management, climate change adaptation, eco-efficient and/or circular economy, and green building projects.	Bhutta et al., 2022
Green loans	Any type of loan instrument made available exclusively to finance or re finance, in whole or in part, new and/or existing eligible green projects.	Same applications as indicated for 'green bonds'.	Mirovic et al., 2023
Green funds	Funds (equityfinancing) that provide clients with platforms through which environmentally friendly businesses and organisations are supported with long term funding.	Climate change and environmentally friendly projects, such as energy efficiency, agriculture and waste management projects.	Silva and Cortez, 2016
Green credits	Green deposit, mortgage, and project loan from lending industry.	Environmental protection, emission reduction, and energy conservation projects; green industries. Investment restriction to high-pollution, high-emission and overcapacity industries, and withdrawal of financing from prohibited industries primarily targeted for their negative environmental impact.	Esposito et al., 2022
Green banking	Green banking facilitates private investments in domestic low-carbon, climate-resilient infrastructure and other green sectors, such as water and waste management.	Meeting ambitious emissions targets, creating jobs, supporting local community development, mobilizing private capital, energy efficient street lighting, lowering the cost of capital, rooftop solar photovoltaic systems, developing green technology markets, and commercial and residential energy retrofits.	Sharma and Choubey, 2022
Green asset-backed securities (ABSs)	Green securitisation involves the conversion of illiquid climate- or green-friendly assets into tradable financial instruments (i.e. securities).	Low-carbon projects.	Lei et al., 2024
Social finance			
Social Impact Bonds	Investment contract with the public sector to achieve financial return on investment, while meeting desired social outcomes.	SROI projects, including community investing, affordable infrastructure (e.g. alternative/clean energy technologies), affordable housing and loans, human rights, political and social activism, and religious value.	Solntsev, 2021
Sustainable finance			
Sustainability (socio-environmental) bonds	Any type of bond instrument where the proceeds or an equivalent amount will be exclusively applied to finance or re-finance a combination of both green and social projects.	Projects combining environmental and social aspects.	Mocanu et al., 2021
Sustainability-linked bonds and sustainability-linked loans	Any type of bond and loan instrument employed by companies and governments to secure capital, often at reduced costs, by committing to achieving predefined sustainability/ESG objectives.	Projects combining environment, social, and governance aspects at the same time.	Mocanu et al., 2021

Source: JRC.

Tailoring the aforementioned new financial products for the NEB also involves rethinking risk assessment models. Traditional models may not accurately capture the complexity of NEB projects and potential long-term benefits. Financial institutions must develop new frameworks for evaluating risks and returns that consider environmental impact, social value, and long-term sustainability. Moreover, offering insurance products and guarantees can help mitigate the perceived risks associated with innovative and sustainable projects. Another crucial aspect is the establishment of investment funds dedicated to supporting NEB projects. These funds would pool capital from investors interested in contributing to sustainable and socially impactful projects, providing a steady financing stream. Furthermore, these funds could offer technical assistance and expertise to projects, ensuring their success and alignment with the NEB vision. Financial tools and models influencing the private and finance sector to effectively support NEB projects are described, as follows:

- *Public-private partnerships (PPPs)* can play a significant role in financing NEB projects. These partnerships (e.g. social impact bond) could leverage public funds to attract private investments, thus reducing the financial burden on both parties, while achieving public interest goals. PPPs can be particularly effective in large-scale urban development projects that embody NEB principles. Although PPPs offer numerous advantages, challenges, such as aligning divergent goals, ensuring transparency, and managing public expectations, need to be considered. Overcoming these challenges requires clear communication, shared objectives, and strong governance structures. Trust is a fundamental component of successful PPPs, necessitating consistent and open dialogue between public and private partners and with the communities they serve.
- *Community-based financing models,* such as crowdfunding or community bonds, can mobilise resources for local projects aligned with the NEB values. These models not only provide the necessary funding, but also foster a sense of ownership and engagement among community members, aligning perfectly with the NEB emphasis on inclusiveness and community involvement.
- *Government incentives* can be a powerful tool in encouraging investments in NEB projects. Tax breaks, subsidies, or grant programs for sustainable and inclusive building projects can make them more financially viable and attractive to investors. Governments can also provide seed funding or matching funds for NEB-aligned projects, drawing particular attention on experimental or community-oriented projects.

However, in the EU evolving financial framework, small and medium size enterprises (SMEs) and even smaller businesses, which are vital for the EU economy and crucial for strategic investments, resilience, and decarbonisation, still rely on bank financing for their operations and innovation. Banks facing economic uncertainty and rising interest rates require a long-term financial instrument for stable funding and efficient asset liability management. Furthermore, in the last years the increasing requirements for EU taxonomy and ESG factors disclosure for large companies and listed SMEs that are required by the Corporate Sustainability Reporting Directive (CSRD) (Directive, 2022) to regularly report on the social and environmental risks they face, and on the impact of their activities on people and environment, according to the European Sustainability Reporting Standards (ESRS) (Commission Delegated Regulation, 2023), create further challenges for obtaining investments, as investors can access company data more easily, potentially influencing their investment decisions. ESG data is even more critical for micro-enterprises, and various public and private initiatives aim to collect and score ESG data for small businesses. An example in this direction refers to the Energy Efficiency Mortage Initiative (EEMI)[3] which aims at implementing the ESG best practices in the financial sector in support to the objectives of the EU Green Deal (COM, 2019) and Renovation Wave (COM, 2020c) strategy, by channeling the private finance towards investment in energy efficient buildings and energy saving renovations. The EEMI has introduced a specific 'harmonised disclosure template', enhancing the overall ESG disclosure for cover pools. ESG has gained prominence in capital markets, but its adoption in covered bond markets has been relatively limited due to data constraints on the ESG attributes of balance sheet assets. Banks have often chosen to use ESG-compliant loans for other types of issuance, like senior preferred or tier 2 bonds, rather than covered bonds. The diversity of investment approaches for applying the ESG factors is evident, and only some investment approaches have a specific ESG mandate covering covered bonds. Some investors rely on the issuer's designation of green or social bonds, while others consider issuer's sustainability ratings, a combination of both, or rely on internal models. In recent years, ESG criteria have become increasingly integrated into issuer and covered bond rating methodologies. This integration is based on how ESG factors impact issuer or bond credit risk. Additionally, external reviewers assign ESG ratings or scores to banks based solely on their ESG performance. Issuers can also obtain external assessments of their green, social, or sustainability bond

[3] Energy Energy Efficient Mortgage Initiative: https://energyefficientmortgages.eu/

processes, including four types of bond-related reviews identified by the International Capital Market Association (Karoui, 2024), as follows:

— *Second-party opinion (SPO):* independent institutions assess the quality of a sustainable bond framework and verify its alignment with relevant principles. For example, Institutional Shareholder Services (ISS ESG) and Sustainalytics often provide second-party opinions for sustainable covered bond frameworks.

— *Verification:* post-issuance, external auditors often verify the allocation of proceeds, sometimes in conjunction with SPO providers.

— *Certification:* issuers can obtain certification of their green, social, or sustainability bonds against recognised external standards or labels. For instance, some green covered bonds are certified by the Climate Bond Initiative to ensure alignment with the goals of the Paris Agreement.

— *Green, social, and sustainability bonds, and sustainability-linked bond scoring/rating*, which assess the performance of issuers or bonds in terms of ESG factors. Imug and ISS ESG are examples of rating agencies that provide such ratings.

In the primary market, ESG-labelled covered bonds tend to attract larger order books and higher cover ratios than conventional counterparts. However, data on new issue premiums are inconclusive. In 2022, ESG-labelled covered bonds had an average new-issue premium 0.4 basis points lower, while in early 2023, it was higher by the same margin. Thus, the pricing advantage associated with an ESG label appears minimal or non-existent for covered bond issuers. Nevertheless, larger order books reduce execution risk and could contribute to more stable secondary-market performance, as ESG investors are often seen as more loyal.

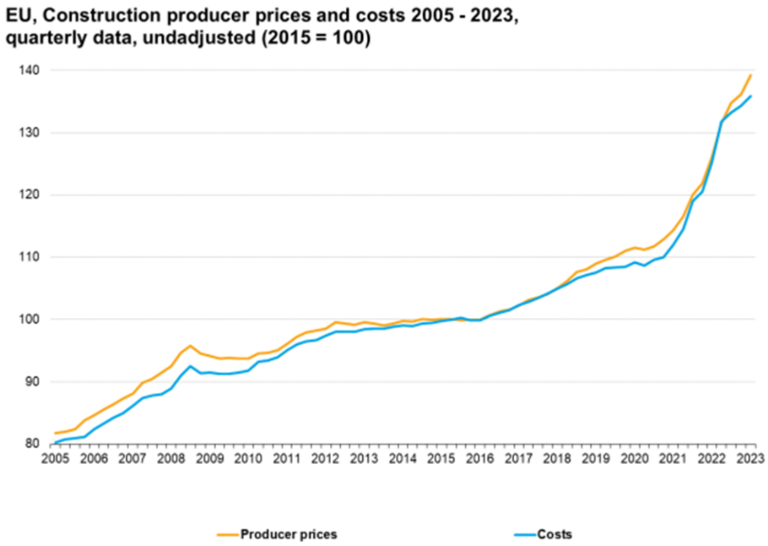
Social and sustainability covered bonds maintain the same high security standards and risk profiles as regular covered bonds, resulting in no significant price difference between comparable issues. However, there could be minimal variations influenced by the broader investor base and increased demand for social and sustainability covered bonds. Determining the relative value of social and sustainability covered bonds compared to regular covered bonds is challenging due to several factors. Covered bond spreads, in general, are compressed, offering limited room for differentiation. Moreover, many issuers do not have bonds with matching tenors in both social/sustainability and regular categories.

3.2.9 Circular Economy

Natural resources scarcity is a key-factor that affects the effectiveness and continuity of economy and production. Overproduction in modern economies to meet the growing needs and desires of the rapidly increasing population requires huge amounts of natural resources which are in gradual depletion. In these conditions, many attempts and initiatives have been undertaken to reduce or even eliminate the consumption of natural resources, to slow the use of materials and to close the cycles of waste materials. These attempts are lately placed under the concept of circular economy that implies that any actor of an economic system should adjust its behavior from a linear to a circular thinking. Engineering principles could assist in closing or slowing the loop of materials such as cradle-to-cradle, performance economy, and industrial ecology.Currently, CE concept has gained great recognition as an effective tool, method, technique, and theory to achieve win–win solutions, such as economic opportunities and environmental protection.The main goal of CE is to shift the focus of the current production system from the linear logic of “take, produce, consume and dispose” to “close the loop”, where the end-of-life products return to the production stage and interventions are made throughout the technical or biological cycles of materials.

The existing broad and well-established link between the built environment and the economic development has caused a tremendous impact on the natural environment and the ecosystems. Specifically, the current development model of the use of resourcses within the built environment is largely unsustainable for three main reasons: (*i*) the depletion of finite natural resources, whereas almost 90 % of all materials extracted and used are wasted, (*ii*) GHG emissions that accelerate climate change, and (*iii*) the inequities and human rights challenges (WGBC, 2023).The construction industry is also a major economic activity in Europe while it consumes about 1094 million tonnes of materials, with the residential sector consuming almost three times the amount of the non-residential sector (CBC, 2023). Construction and demolition waste is one of the largest waste generation in the European Union. In 2018, the total waste generated in the EU amounted to 2317 million tonnes, of which 36 % was generated from the construction sector. Including waste from mining and quarrying almost two thirds (1.505 million tons) of the total waste generated was major mineral waste (Eliote and Leite, 2022; Moschen-Schimek et al., 2023). The construction industry is also exposed to high prices, extended linear supply chain disruptions and global volatility. Although construction materials represent one of the main inputs in the construction process, recent prices of input materials have very closely correlated with construction output prices for new residential buildings in the EU (Figure 9).

Figure 9. EU construction prices and costs during the period 2005-2023.



Source: Eurostat, 2023e.

Based on these figures, the transition to a circular economy within the built environment is urgent to ensure resource efficiency and also provide opportunities to decouple economic growth from carbon emissions. In this context, a circular building is defined as a building that "*optimises the use of resources whilst minimising waste throughout its whole lifecycle*" (WBCSD, 2021), thus circular buildings should be designed to reduce waste and pollution, while promoting the reuse of construction products and materials, and facilitating the regeneration of natural systems, according to three main CE principles, i.e. (*i*) eliminate waste and pollution, (*ii*) circulate products and materials, and (*iii*) regenerate nature (Ellen MacArthur Foundation, 2021). However, the measurement of the circularity level of a building still remains a complex issue. The implementation of the aforementioned three CE principles to the built environment may address this challenge by identifying specific measurements needed to align to each principle and determining relevant actions to improve circularity (WBCSD, 2022a), as summarised in Table 4. Further analyses and findings concerning the circular economy within the built environment can be found in relevant reports indicated in Annex A.

Table 4. Circular principles applied to the built environment.

Circular principle[1]	**Measurements and actions**
1. *Eliminate waste and pollution*	Measure emissions, and air, land and water pollution, as well as structural sources of pollution, such as traffic, to be considered for the in-use stage of a building, but also for different life cycle stages, such as construction, maintenance and demolition. Enable and measure reuse, refurbishment, remanufacturing (and recycling as a last resort) and identify end-of-use options for new assets, materials and products installed. Ensure collaboration across the supply chain and defined end-of-life options or closed loop supply chains within contracts.
2. *Circulate products and materials.*	Measure and reduce energy, labor and material use across a building lifecycle, thus considering how the building is being used and how this use could be extended and dematerialised. Measure and reduction of products and material altogether, such as inherent finishings avoiding the need for paint, or exposed ceilings.Measure and understand longevity to determine the durability or adaptability and ease of reconfiguration of elements within a building. Consider design for disassembly and deconstruction to enable the repair and reuse of building products and material that can be easily separated, swapped out and recycled.
3. *Regenerate nature.*	Measure the use of renewable materials and energy, with particularattention upon the materials regenerative in nature.

[1] CE principles as defined in Ellen MacArthur Foundation (2021).

Source: Adapted from WBCSD, 2022a.

Other barriers to be faced when designing a circular building mainly concern the adoption of materials with circular features due to cost competitiveness, complex certification processes and lack of appropriate regulations that do not incentivise the use of alternative materials compared to traditional ones (WGBC, 2023). The current lack of standardisation also results in the need for various certifications, which are costly and time-consuming. Currently, there is no uniform circularity standard for a project evaluation and assessment, which further complicates the identification of the 'value' of a circular building for an investment portfolio, thus resulting into a higher risk and less transparent sector than the traditional building sector (CBC, 2023). However, in 2021 a standardisation effort was initiated at European level, by establishing the subcommittee (SC) of the Technical Committee (TC) 350 of the Comité Européen de Normalisation (CEN), i.e CEN/TC 350/ SC 1 – Circular economy in the construction sector, to develop standards in the field of circular economy in the built environment aimed at providing principles, guidelines, and requirements to facilitate the transition to a more sustainable circular economy in all stages of life cycle of construction projects. This ongoing work will consider the standardisation effort carried out at international level by the TC 323 of the International Organization for Standardization (ISO), i.e. ISO/TC 323 - Circular economy, to develop six new standards to foster the shift towards a circular economy by developing frameworks, guidance and requirements for the implementation of circular economy activities of organisations. Specifically, four out of the six standards are currently published, focusing on (*i*) the definition of key terms, concepts and guidance applicable to any type of public or private organisation, i.e. ISO 59004 (ISO, 2024a), (*ii*) business-oriented strategies to implement circular economy practices at both organizational and inter-organizational levels, i.e. ISO 59010 (ISO, 2024b), (*iii*) a framework, applicable at regional, organizational, inter-organizational or product level, to measure and assess the circularity performance based on mandatory and optional indicators, i.e. ISO 59020 (ISO, 2024c), and (*iv*) the review of characteristics of value networks as examples in accelerating the circular economy transition, i.e. ISO 59032 (ISO, 2024d).

Additionally, another barrier towards a consolidated approach to the circular design of buildings concerns the lack of examples and case studies integrating more than one aspect of the circular economy. Currently, it still seems complex to find project analyses in which different resources (e.g. materials, energy, and water) are considered and monitored at the same time in a circular approach. Even when very few demonstration projects in this direction are available, they are usually developed at a small scale, which is ineffective in drawing any robust conclusion on circularity performance assessment. Hence, investment in circular building projects at least at neighbourhood or larger scale are needed to demonstrate and measure the circularity benefits. However, recently interesting steps to overcome this gap at building scale have been carried out through case studies available for Level(s) in its eLearning modules[4] explaining the principles and concepts for applying circular economy principles in the built environment. Another example in this direction is the 2019-2022 Life for LCA LCC Level(s) project[5] (also known as LIFE project) directed towards mainstreaming sustainable buildings in Europe through greater awareness and use of specific indicators, i.e. Life cycle assessment (LCA), Life cycle costing (LCC) and Indoor air quality (IAQ), within the framework of Level(s). The idea behind the LIFE project is to work with stakeholders form the public, private and certification schemes to explore how the mentioned key Level(s) indicators can be implemented at a pan-European scale for building assessment.

3.3 Selection criteria and list of KPIs

A detailed literature review was first carried out to identify and map relevant scientific areas and criteria addressing environmental issues related to the built environment in line with (*i*) relevant Sustainable Development Goals (SDGs) of the United Nations (UN) 2030 Agenda for Sustainable Development (UN, 2015b), including the SDG 6 to preserve clean water, the SDG 7 for affordable and clean energy, the SDG 11 for sustainable cities and communities, and the SDG 12 for responsible consumption and production patterns through resource and energy efficiency, and (*ii*) EU efforts contributing to the implementation of these goals through policies and initiatives (Eurostat, 2024a) channelling global environmental challenges.

The selected KPIs and their corresponding indicators relevant to the environmental perspective of the Sustainability dimension were derived from a plethora of indicators and metrics that are commonly used in voluntary and commercial rating systems, also known as green building rating systems, based on a multi-criteria approach providing the sustainability assessment of a building to award a corresponding certificate (Mattoni et al., 2018). Specifically, the investigation was focused on both European, e.g. BREEAM[6]

[4] Level(s) eLearning: https://academy.europa.eu/courses/level-s-sustainable-performance-in-buildings
[5] LIFE Level(s) project: https://lifelevels.eu/
[6] Building Research Establishment Environmental Assessment Method (BREEAM): https://breeam.com

(UK), ITACA Protocol[7] (Italy), and non-European, e.g. LEED[8] (USA), Green star[9] (Australia), CASBEE[10] (Japan) rating systems, along with standards on green building design, such as the ASHRAE Standard 189.1 (ASHRAE, 2023a). The work also aligned with Level(s), which is a voluntary reporting framework developed by the European Commission in 2020 to improve the sustainability of buildings based on a common system of indicators (Dodd et al., 2021a). Level(s) is being used in EU policy and other instruments like the EPBD, EU taxonomy and green public procurement, while impacting commercial certification schemes (Donatello et al., 2022). Indeed, the heterogeneity of the available rating systems leads to various drawbacks, such as the difficult comparability of the final score of an assessment. Moreover, the rating systems include distinctive local features specific of the regional characteristics of the area where the tool was developed, limiting their application globally. Only few rating systems provide international versions enabling their application by other countries or regions apart from the origin country, such as BREEAM, and LEED, thus Level(s) represented a significant attempt to overcome the difficulty of managing the extensive heterogeneity of the existing certification schemes. Level(s) effort to develop a holistic transparent and regionally adaptable tool supports circular economy principles in the built environment across the whole life cycle of a building, focusing on GHG emissions, resource efficiency, and water use. Level(s) complements the NEB initiative by identifying measures to improve the sustainability of European buildings at each stage of their life cycle.

The selection criteria for the economic aspects of the Sustainability dimension of the NEB paradigm mainly concerned a review of relevant frameworks and tools for greening the public sector focusing on the promotion of public investments in low emission assets and green economy, as well as on the implementation of decarbonisation activities. Other analyses referred to the social return of investment methodology and the economic spillover effects of the public investment. Indicators incorporating green financial tools, the financing of sustainable real estate investments, as well as the promotion and implementation of ESG factors and investments were analysed with reference to the greening of private and finance sector. Finally, studies on the degree of circularity of materials were investigated to elaborate relevant indicators fostering the circular economy within the built environment.

Following the review and analysis phase, the final selection and elaboration of relevant indicators, reflecting the sustainability priorities within the NEB initiative, came as a result of various efforts to (*i*) converge to a manageable number of commonly used indicators, (*ii*) identify consistently measurable indicators based on relevant standards, well established common practices and other consolidated methodologies, and (*iii)* ensure the development of quantitative indicators. As a result of this process, nine KPIs have been developed within the Sustainability dimension to evaluate the specific assessment targets at the different spatial scales, types, and main uses of a project.

The **KPIs** within the **Sustainability** dimension together with the associated **indicators** and **indicator weights ($w_{S.i.j}$)** are provided in Table 5 that also reports the **KPI weights ($w_{S.i.}$)**. The same table also presents the field of application and consideration of indicators according to the project classification based on scale, type, main use and relevance to cultural heritage.

Additional information on each KPI is provided in Sections 3.4-3.12, including the rationale, background, calculation method, and input data needed for the evaluation. The calculation method addresses the evaluation of indicator scores, KPI scores and KPI performance classes according to Sections 2.2.1 and 2.2.2.

Table 5. Key performance indicators (KPIs) within Sustainability.

KPI[1]	Weight ($w_{S.i.}$)	Indicator	Scale	Type	Main use	Cultural heritage[2]	Weight ($w_{S.i.j}$)
Minimise the use of fossil fuels in the built environment (S.1)	0.15	Primary energy demand (S.1.1)	Building	Newbuild	Residential	Not affected	0.3
		Electricity peak demand (S.1.2)				Not affected	0.45
		Smart readiness (S.1.3)				Not affected	0.25
		(S.1.1)	Building	Newbuild	Non-residential	Not affected	0.25
		(S.1.2)				Not affected	0.5
		(S.1.3)				Not affected	0.25

[7] Institute for Innovation and Transparency of Procurements and Environmental Compatibility (ITACA) Protocol: https://www.proitaca.org/
[8] Leadership in Energy and Environmental Design (LEED): https://www.usgbc.org/leed
[9] Green Star: https://new.gbca.org.au/
[10] Comprehensive Assessment System for Built Environment Efficiency (CASBEE): https://www.ibecs.or.jp/CASBEE/english/

KPI[1]	Weight ($w_{S.i.}$)	Indicator	Scale	Type	Main use	Cultural heritage[2]	Weight ($w_{S.i.j}$)
	0.2	(S.1.1)	Building	Renovation	Residential	Not affected	0.55
		(S.1.2)				Not affected	0.25
		(S.1.3)				Not affected	0.2
		(S.1.1)	Building	Renovation	Non-residential	Not affected	0.5
		(S.1.2)				Not affected	0.25
		(S.1.3)				Not affected	0.25
	0.15	Primary energy demand (S.1.1)	Neighbourhood/ Urban	Newbuild	Residential	Not affected	0.6
		Smart energy meters (S.1.3)				Not affected	0.4
		(S.1.1)	Neighbourhood/ Urban	Newbuild	Non-residential	Not affected	0.3
		(S.1.3)				Not affected	0.7
		(S.1.1)	Neighbourhood/ Urban	Renovation	Residential	Not affected	0.75
		(S.1.3)				Not affected	0.25
		(S.1.1)	Neighbourhood/ Urban	Renovation	Non-residential	Not affected	0.55
		(S.1.3)				Not affected	0.45
Maximise the use of sustainable energy in the built environment (S.2)	0.15	Share of renewables (S.2.1)	Building	Newbuild	Residential	Not affected	0.35
		Energy storage (S.2.2)				Not affected	0.65
		(S.2.1)	Building	Newbuild	Non-residential	Not affected	0.3
		(S.2.2)				Not affected	0.7
	0.1	(S.2.1)	Building	Renovation	Residential	Not affected	0.55
		(S.2.2)				Not affected	0.45
		(S.2.1)	Building	Renovation	Non-residential	Not affected	0.55
		(S.2.2)				Not affected	0.45
	0.2	Share of renewables (S.2.1)	Neighbourhood/ Urban	Newbuild	Residential	Not affected	0.45
		Energy storage (S.2.2)				Not affected	0.55
		(S.2.1)	Neighbourhood/ Urban	Newbuild	Non-residential	Not affected	0.65
		(S.2.2)				Not affected	0.35
	0.15	(S.2.1)	Neighbourhood/ Urban	Renovation	Residential	Not affected	0.65
		(S.2.2)				Not affected	0.35
		(S.2.1)	Neighbourhood/ Urban	Renovation	Non-residential	Not affected	0.45
		(S.2.2)				Not affected	0.55
Minimise greenhouse gas emissions from the built environment (S.3)	0.15	Operational GHG emissions (S.3.1)	Building	Newbuild	Residential	Not affected	0.4
		Embodied GHG emissions (S.3.2)				Not affected	0.6
		(S.3.1)	Building	Newbuild	Non-residential	Not affected	0.35
		(S.3.2)				Not affected	0.65
	0.1	(S.3.1)	Building	Renovation	Residential	Not affected	0.6
		(S.3.2)				Not affected	0.4
		(S.3.1)	Building	Renovation	Non-residential	Not affected	0.55
		(S.3.2)				Not affected	0.45

KPI[1]	Weight ($w_{S.i.}$)	Indicator	Scale	Type	Main use	Cultural heritage[2]	Weight ($w_{S.i.j}$)
		Operational GHG emissions (S3.1)	Neighbourhood/ Urban	Newbuild	Residential	Not affected	0.45
		Carbon sequestration (S3.2)				Not affected	0.55
		(S.3.1)	Neighbourhood/ Urban	Newbuild	Non-residential	Not affected	0.4
		(S.3.2)				Not affected	0.6
		(S.3.1)	Neighbourhood/ Urban	Renovation	Residential	Not affected	0.65
		(S.3.2)				Not affected	0.35
		(S.3.1)	Neighbourhood/ Urban	Renovation	Non-residential	Not affected	0.6
		(S.3.2)				Not affected	0.4
Enhance sustainable mobility in the built environment (S.4)	0.05	e-Mobility: electric vehicle (EV) parking (S.4.1)	Building	Newbuild	Residential	Not affected	0.7
		Alternative mobility: bicycle (S.4.2)				Not affected	0.3
		(S.4.1)	Building	Newbuild	Non-residential	Not affected	0.75
		(S.4.2)				Not affected	0.25
		(S.4.1)	Building	Renovation	Residential	Not affected	0.7
		(S.4.2)				Not affected	0.3
		(S.4.1)	Building	Renovation	Non-residential	Not affected	0.75
		(S.4.2)				Not affected	0.25
		e-Mobility: electric vehicle (EV) parking (S.4.1)	Neighbourhood/ Urban	Newbuild	Residential	Not affected	0.2
		Alternative Mobility: bicycle (S.4.2)				Not affected	0.15
		Public transportation systems: extend (S.4.3)				Not affected	0.2
		Public transportation systems:usage (S.4.4)				Not affected	0.25
		Public transportation systems: accessibility (S.4.5)				Not affected	0.2
		(S.4.1)	Neighbourhood/ Urban	Newbuild	Non-residential	Not affected	0.2
		(S.4.2)				Not affected	0.15
		(S.4.3)				Not affected	0.2
		(S.4.4)				Not affected	0.2
		(S.4.5)				Not affected	0.25
		(S.4.1)	Neighbourhood/ Urban	Renovation	Residential	Not affected	0.25
		(S.4.2)				Not affected	0.15
		(S4.3)				Not affected	0.15
		(S.4.4)				Not affected	0.25
		(S.4.5)				Not affected	0.2
		(S.4.1)		Renovation	Non-residential	Not affected	0.25

KPI[1]	Weight ($w_{S.i.}$)	Indicator	Scale	Type	Main use	Cultural heritage[2]	Weight ($w_{S.i.j}$)
		(S.4.2)	Neighbourhood/ Urban			Not affected	0.15
		(S.4.3)				Not affected	0.15
		(S.4.4)				Not affected	0.2
		(S.4.5)				Not affected	0.25
Minimise non-energy related environmental impacts to air and water (S.5)	0.05	Indoor air quality (S.5.1)	Building	Newbuild	Residential/ Non-residential	Not affected	0.7
		Water consumption (S.5.2)				Not affected	0.3
	0.1	(S.5.1)	Building	Renovation	Residential/ Non-residential	Not affected	0.7
		(S.5.2)				Not affected	0.3
	0.05	Ground water recharge: permeability (S.5.2)	Neighbourhood/ Urban	Newbuild	Residential/ Non-residential	Not affected	1
	0.1	(S.5.2)	Neighbourhood/ Urban	Renovation	Residential/Non-residential	Not affected	1
Minimise non-energy related environmental impacts from the built environment (S.6)	0.05	Construction and demolition waste (S.6.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	1
Achieve the best possible greening of the public sector in terms of its economic involvement in sustainability of the built environment (S.7)	0.12	Social return of investment (S.7.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
		Degree of interdisciplinary integration (S.7.2)					0.2
		Gross value added to local economy from new business creation (S.7.3)					0.5
Achieve the best possible greening of the private and financial sector in terms of its economic involvement in sustainability of the built environment (S.8)[3]	0.15	Green financial tools (S.8.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.5
		Compliance with ESG standards and European Sustainability Reporting Standards for green transition investment from private companies (S.8.2)					0.5
Promote circular economy in the built environment (S.9)	0.13	Secondary, bio-based, recycled materials (S.9.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	1

[1] Although minimum KPI scores are not prescribed in the NEB self-assessment method, it is highly recommended that all KPIs attain the Acceptable performance class.

[2] Yes: Indicator applicable only to cultural heritage; No: Indicator non-applicable to cultural heritage; Not affected: Indicator applicable irrespective of cultural heritage.

[3] Additional conditions apply: in the case of S.8, the S.8.2 indicator is included in the self-assessment of a project based on the condition that at least one of any potential private company involved in the project fulfils sustainability reporting obligations according to European Sustainability Reporting Standards. If this condition is not satisfied, S.8.2 is omitted and users utilise exclusively S.8.1 indicator.

Source: JRC.

The **KPI performance class scores** (PCS) assigned to all KPIs of the Sustainability dimension, as a function of the attained KPI performance class and KPI score (Section 2.2.3) are provided in Figure 10.

Figure 10. KPI performance class scores (PCS) in the Sustainability dimension.

Performance class:	Low	Acceptable	Good	Excellent
KPI performance class score (PCS):	25	45	70	100

Source: JRC.

The Sustainability (S) **dimension score** (Section 2.2.4) is evaluated according to Equation (5), as a weighted average of KPI performance class scores. All nine KPIs are always considered within the equation; however, the weight of each KPI ($w_{S,i}$) varies depending on the different combinations of project classification according to scale, type and main use (Table 5), so that the denominator of the equation always equals the unity.

$$S = \sum_{i=1}^{9} (w_{S.i} \cdot PCS_{S.i}) \Big/ \sum_{i=1}^{9} (w_{S.i}) \quad (5)$$

The Sustainability **dimension performance class** is assessed considering the dimension score and the dimension thresholds, according to Figure 11.

Figure 11. Sustainability performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
Sustainability dimension thresholds (t_S):	$0 \leq$		$t_{S,\ Acceptable}$ ≥ 40		$t_{S,\ Good}$ ≥ 60		$t_{S,\ Excellent}$ ≥ 80		≤ 100

Source: JRC.

3.4 Minimise the use of fossil fuels in the built environment (S.1)

3.4.1 Description and assessment

At **building scale**, *minimise the use of fossil fuels in the built environment (S.1)* KPI is assessed through the following three indicators:

— *Primary energy demand improvement (S.1.1).*

— *Optimisation of electricity peak demand for building operations (S.1.2).*

— *Smart readiness of buildings (S.1.3).*

S.1 score at building scale is evaluated according to Equation (6) using different indicator weights ($w_{S.1.j}$) depending on the different combinations of the project classification according to type (i.e. newbuild or renovation)/main use (i.e. residential or non-residential) of a building scale project, as reported in Table 5. It is worth noting that the denominator of Equation (6) equals unity for each combination. As example, the indicator weights within Equation (6) refer to a project classified as building scale, newbuild type, and residential main use.

$$S.1 = \sum_{j=1}^{3} (w_{S.1.j} \cdot S.1.j) \Big/ \sum_{j=1}^{3} (w_{S.1.j}) = 0.3 \cdot S.1.1 + 0.45 \cdot S.1.2 + 0.25 \cdot S.1.3 \quad (6)$$

S.1 thresholds to associate the KPI score to the corresponding KPI performance class, at the building scale, are illustrated in Figure 12.

Figure 12. S.1 performance classes and thresholds at building scale.

Performance class:	Low	Acceptable	Good	Excellent	
S.1 thresholds ($t_{S.1}$):	$0 \leq$	$t_{S.1,\ Acceptable}$	$t_{S.1,\ Good}$	$t_{S.1,\ Excellent}$	≤ 100
Newbuild - Residential		≥ 25	≥ 50	≥ 80	
Newbuild - Non-residential		≥ 30	≥ 55	≥ 85	
Renovation - Residential		≥ 20	≥ 45	≥ 75	
Renovation - Non-residential		≥ 25	≥ 50	≥ 80	

Source: JRC.

At **neighbourhood/urban scale**, *Minimise the use of fossil fuels in the built environment (S.1)* KPI is assessed through the following two indicators:

— *Primary energy demand improvement (S.1.1).*

— *Smart energy meters (S.1.3).*

The S.1.2 indicator, considered at building scale, is not applicable for the neighbourhood/urban scale projects. Accordingly, S.1.2 is omitted in the evaluation of S.1 score at neighbourhood/urban scale. The S.1 score is evaluated according to Equation (7) using different indicator weights ($w_{S.1.j}$) depending on the different combinations of the project classification according to type (i.e. newbuild or renovation)/main use (i.e. residential or residential/non-residential) of a neighbourhood/urban project, as indicated in Table 5. It is worth noting that the denominator of Equation (7) equals unity for each combination. As example, the indicator weights within Equation (7) refer to a project classified as neighbourhood scale, newbuild type and residential main use.

$$S.1 = \sum_{j=1}^{3} \left(w_{S.1.j} \cdot S.1.j\right) \Big/ \sum_{j=1}^{3} \left(w_{S.1.j}\right) = 0.6 \cdot S.1.1 + 0.4 \cdot S.1.3 \tag{7}$$

The S.1 thresholds to associate the KPI score to the corresponding KPI performance class at the neighbourhood/urban scale are illustrated in Figure 13.

Figure 13. S.1 performance classes and thresholds at neighbourhood/urban scale.

Performance class:	Low	Acceptable	Good	Excellent	
S.1 thresholds ($t_{S.1}$):	$0 \leq$	$t_{S.1,\ Acceptable}$	$t_{S.1,\ Good}$	$t_{S.1,\ Excellent}$	≤ 100
Newbuild - Residential		≥ 40	≥ 70	≥ 90	
Newbuild - Non-residential		≥ 35	≥ 65	≥ 85	
Renovation - Residential		≥ 25	≥ 55	≥ 80	
Renovation - Non-residential		≥ 15	≥ 50	≥ 75	

Source: JRC.

The S.1 KPI and its corresponding indicators can be generally implemented in the self-assessment of any project irrespective of its scale/type/main use. However, special attention should be drawn upon cultural heritage buildings since minimum requirements in relevant energy-related EU directive, such as the recast EPBD (Directive, 2024), may allow EU Member States to exclude this category of buildings from meeting NZEBs and/or zero-emissions building-targets in their national codes/regulations. Nevertheless, interventions to reduce the primary energy demand and the electricity peak demand can also be considered for historic buildings and heritage areas, carefully evaluating the feasibility of potential options case by case. The smart readiness is independent from the nature of a building, thus the possible unique characteristics and limitations of cultural heritage buildings do not prevent the applicability of the smart readiness indicator. However, an ad hoc evalution when dealing with cultural heritage is essential.

3.4.2 Primary energy demand (S.1.1)

At **building scale**, S.1.1 is evaluated based on the Level(s) indicator 1.1 'Use stage energy performance' for the primary energy demand (Dodd et al., 2021b), according to the following standards at international level: ISO 52000-1 (ISO, 2017a), ISO 52003-1 (ISO, 2017b), ISO 52010-1 (ISO, 2017c), ISO 52016-1 (ISO, 2017d), and ISO 52018-1 (ISO, 2017e). The indicator focuses on both the primary energy demand of the technical systems of the building and the efficiency of the building envelope, and the delivered energy demand that can subsequently be monitored using data from metering. Specifically, S.1.1 evaluates the annual primary energy demand for the use stage of a building scale project per internal useful floor area (expressed as kWh/m^{2}year). The primary energy demand is related to various energy carriers, delivered to the building and used in the form of electricity, heat and fuel, to satisfy the uses within the building. The delivered energy is generally the one metered by the utilities. Reporting is therefore disaggregated into the energy used for heating, cooling and dehumidification, ventilation, and humidification; hot water; and lighting (optional for residential buildings) according to ISO 52000-1 (ISO, 2017a). National bodies decide if the energy consumption for lighting in residential buildings, as well as energy for other services (e.g. electrical appliances, cooking, industrial processes) in all types of buildings shall be included or not in the assessment. The primary energy use is based on primary energy factors per energy carrier, which are derived from national or regional annual weighted averages or a specific value for on-site production. At the design stage, the energy needs can be converted into primary energy by applying the relevant primary energy factors. These factors account for any system losses and inefficiencies.

Energy can be imported or exported from/to the building from on-site, nearby, and distant energy generators. Inside the assessment boundary, primary energy factors shall apply to all forms of energy generation that supply the delivered energy needs of the building, as well as any exports.S.1.1 score, which ranges from 0 to 100, is evaluated according to a four-step framework that consecutively estimate the score of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Annual delivered energy demand (E_{del}) sub-metric evaluation:* the annual delivered energy is also referred to as annual final energy consumption. The energy is expressed per energy carrier (i), supplied to the technical building systems through the assessment boundary, thus delivered to the building in the form of electricity, heat and fuel to satisfy the building services according to ISO 52000-1 (ISO, 2017a). Specifically, the delivered energy for all building services included in the energy performance assessment is used for heating, cooling and dehumidification, ventilation, and humidification; hot water; and lighting (optional for residential buildings) according to ISO 52000-1 (ISO, 2017a). Additional building services can be integrated depending on the use of the building (e.g. office, retail, etc.) and shall be reported separately. The annual delivered energy demand per energy carrier can be quantified according to standardised procedures. The starting point for estimating the delivered energy demand is the thermal performance of the building envelope (i.e. energy need), while the following main input data items and their corresponding available resources in terms of international and European standards are considered:

   — Conditions of use and occupancy according to ISO 52000-1 (ISO, 2017a), ISO 52016-1 (ISO, 2017d).

   — Thermal envelope description according to ISO 52016-1 (ISO, 2017d).

   — Building services description according to ISO 52016-1 (ISO, 2017d).

   — Primary energy factors according to ISO 52000-1, Annex B.10 (ISO, 2017a).

   — Internal temperature set points according to ISO 52016-1 (ISO, 2017d).

   — Ventilation and infiltration rates according to EN 16798-5-1 (CEN, 2017a) and EN 16798-7 (CEN, 2017b).

   — Internal gains as heat flows according to ISO 52016-1 (ISO, 2017d).

   The evalution of the annual delivered energy demand relies on different approaches depending on newbuild or renovation projects, as follows:

   a) **Newbuild projects**, the energy needs of the building are first estimated and the efficiency of different technologies is considered to quantify the delivered energy demand. Electricity loads associated with occupancy, such as, plug loads for appliances or computers, are not specifically covered in most national or regional assessments, thus corresponding to unregulated energy needs that are reported separately, if they are estimated.

b) **Renovation projects** of existing buildings, the delivered energy can be measured directly from the meters and the utility (energy) bills, thus it is more appropriate for existing buildins to use metered data than proceeding with estimation as for new buildings.

Building scale simulation tools that have been validated according to available standardised procedures (ISO, 2017d, ASHRAE, 2023b) should be used to perform the assessment of the annual delivered energy demand. Examples of energy simuation tools include DOE2, BLAST, ESP, SRES/SUN (SERIRES/SUNCODE), SERIRES, S3PAS (LIDER/CALENER), TAS, TRNSYS, EnergyPlus, among many others. Setting up a simulation model may be time-consuming, as it requires detailed inputs about a building. It is also recommended to assess the local climate: a good example in this direction is the tool Climate Consultant or the collection of data from the International Weather for Energy Calculation and the use of weather files for a Typical Meteorological Year, according to standardised climatic data (ISO, 2005).

Measured data for existing buildings can be used to quantify the delivered energy demand per energy carrier by considering the average over several most recent full years, as long as the building and its use pattern have been the same. If the period is shorter than three years, a weather correction shall be performed (ISO, 2017a). Measured data can be retrieved from different sources, as follows:

- Data can be obtained from utility bills issued by service providers/utilities (e.g. electricity, natural gas).
- Measured data shall be obtained from meters and sub-meters, or from a building energy management system, if available. The amounts of all energy carriers delivered to the building and exported by the building shall be measured and reported.
- Estimated annual amounts of fuels can be used if these are not automatically metered (e.g. liquid and solid fuels as oil or coal).

Focusing on the first source concerning the utility bill data, the retrieved values represent the total energy demand of the building, thus making it challenging to reconstruct the energy consumption for specific end uses, e.g. electricity from the main meter or natural gas used for space heating and cooking. In case the only source for measured data are utility bills, it is necessary to have an end-use breakdown for the default building services. Specifically, different approaches for electricity and fuel energy carrier can be taken into account to overcome this issue.

As for **electricity**, the following three approaches are available. The first approach regards the use of the statistical electricity profiles from national studies and databases (e.g. Odysee-Mure data tools[11]; Eurostat, 2024b) that provide electrical energy consumption profiles for each end-use. The second approach consists in listing every electrical device, and estimate both its use frequency on an annual basis and its annual energy use based on its technical specifications. The third approach exploits the use of assessment methods to subsequently calibrate the results with measured data from the utility bills, or the use of simulation tools to generate the end-use breakdown.

As for **fuels**, when the energy carrier is used for heating, cooking, and DHW, the following two approaches are available. The first approach consistis in determining the baseloads by separately analysing the seasonal consumption (winter and summer) to differentiate space heating from cooking and DHW. The DHW consumption of the building can be estimated depending on floor area or per person using national statistics or European tools (e.g. TABULA web tool) and databases (e.g. Eurostat, 2024b); estimate consumption for cooking. The second approach concerns the assessment of the thermal delivered energy demand based on standards to subsequently calibrate the measured data with simulations to obtain the end-use breakdown.

Furthermore, measured data should be normalised to account for weather, occupancy and operation, and energy services variations. Regarding the weather, correction from actual to standard weather conditions needs to be considered by using long time periods (e.g. average three-year data) or the common practice for correcting with average heating degree days (HDD) and cooling degree days (CDD) from Eurostat. Regarding occupancy and operation, the correction from the actual to the standard occupancy pattern needs to be examined by using occupancy profiles according to the European standard EN 16798-1 (ANNEX A8) (CEN, 2019), and the international standards ISO 52000-1 (ISO, 2017a), and ISO 52016-1 (ISO, 2017d). Building surveys to provide additional refinement and better understanding of occupancy patterns and user behaviour can be also used. Regarding the energy services, it is essential to include only the

[11] http://www.odyssee-mure.eu/data-tools

energy services that are accounted in the assessment by using estimated data to correct total measured energy data for all services.

2. *Total annual delivered energy demand per useful floor area ($E_{del,i,Au}$) sub-metric evaluation*: the annual delivered energy demand for the different energy carriers (i) (evaluated in step 1) needs to be estimated per useful internal floor area (A_u), expressed in kilowatt-hours (kWh/m^2 year). The useful internal floor area refers to the area of the floor of a building needed as a parameter to quantify specific conditions of use that are expressed per unit of floor area and for the application of the simplifications and the zoning and (re)allocation rules, according to the recast EPBD (Directive, 2024).

3. *Total annual primary energy demand per useful floor area ($E_{pri,Au}$) metric evaluation:* the annual primary energy demand (E_{pri}) is estimated by considering the delivered ($E_{del,i}$) and exported ($E_{exp,i}$) (if any) energy per energy carrier (*i*), according to Equation (8). Specifically, the delivered energy demand for each energy carrier ($E_{del,i}$) and the exported energy per energy carrier ($E_{exp,i}$) is multiplied with the corresponding regional or national primary energy factors (PEF) to convert the delivered and exported energy to the primary energy. In Equation (8), $PEF_{del,i}$ is the primary energy factor for the delivered energy carrier (i), and $PEF_{expl,i}$ is the primary energy factor for the exported energy carrier (i). The results can be disaggregated in non-renewable and renewable components and it is recommended to use national PEF values, especially for electricity (Amann et al., 2023). Several approaches/methods to determine the PEFs are indicated in the European standard EN 17423 (CEN, 2020). However, default PEF, if necessary, for on-site, nearby, or distant energy sources are available from ISO 52000-1 (ISO, 2017a) and RED (Directive, 2023b).

$$E_{pri} \;=\; \Sigma\left(E_{del,i}\cdot\;PEF_{del,i}\right) - \Sigma\left(E_{exp,i}\cdot\;PEF_{exp,i}\right)\;\left[\frac{kWh}{year}\right] \qquad (8)$$

The annual primary energy demand may be zero in case the building may export as much energy it may be delivered to the building on an annual basis. This does not mean that there is no energy crossing the building boundary, but on an annual basis, as much primary energy is generated and exported from the building using renewables (e.g. electricity from photovoltaics) as the amount of delivered primary energy. For net positive primary energy buildings, the annual primary energy demand will get a negative value. This refers to the notion that on average over the year there is a surplus of exported energy. To account for this new era of high-performance buildings, the baselines used for the benchmarking will have to be adapted accordingly and interpret the indicators accordingly based on how much more primary energy is exported.

The annual primary energy demand (E_{pri}) needs to be normalised per unit floor area, thus the the $E_{pri,Au}$ is estimated according to Equation (9).

$$E_{pri,Au} = \frac{E_{pri}}{A_u}\;\left[\frac{kWh}{m^2 year}\right] \qquad (9)$$

4. *S.1.1 score evaluation*: the S.1.1 score is assessed according to Equation (10) as a ratio in which the numerator is the difference of the a baseline ($T_{baseline}$) metric score and the annual primary energy demand per useful floor area *($E_{pri,Au}$)* metric score (evaluated in step 3) and the denominator is the score of the same baseline metric. The ratio is multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100. The $T_{baseline}$ metric score indicates the average of the primary energy demand of a baseline building/building stock set as a threshold. Hence, the S.1.1 score provides indications of the improved primary energy of a building against a baseline metric score that can be set at the local-national level or EU level.

$$S.1.1 = \frac{T_{baseline} - E_{pri,Au}}{T_{baseline}} \cdot 100 \qquad (10)$$

If the $E_{pri,Au}$ metric score is lower than the $T_{baseline}$ metric score, S.1.1 results into a positive score. The higher the indicator score, the better the building performance towards the EU 2030 energy targets and the greater the reduction of the primary energy demand, noting though that the indicator maximum score is 100. If the $E_{pri,Au}$ metric score is greater than the baseline metric score, leading the difference in the numerator to be negative, S.1.1 results into a negative score indicating that the building performance does not satisfy the baseline metric, providing an increase of the primary energy demand compared to the baseline metric, thus the indicator score is assumed equal to zero (0). Specifically, a building exhibiting an energy performance corresponding to the baseline metric score will reach a S.1.1 score equal to 0, whereas a zero-emission or a NZEB reduced by 10 % based on local and national targets for 2030 will obtain a S.1.1 score equal to 100. A S.1.1 score greater than 32.5 is considered positive in relation to the climate goal of reducing EU emissions by at least 32.5 % by 2030. The indicator tracks the progress towards the EU building stock by 2050. Buildings should at least meet the minimum requirements for the primary energy demand.

The score of the baseline metric to be used in Equation (10) is not constant, as it is defined at national or EU level, for different types of buildings and climate zones. Specifically, the $T_{baseline}$ score is determined as the average annual primary energy demand per useful floor area of the building stock, at national or EU-27 level, to which the building belongs. Using the baseline metric score at EU level, it is possible to assess the performance of a building in relation to the EU 2030 and 2050 GHG reduction targets, while using a baseline metric score at national level, it is possible to assess the performance of a building in relation to the national building stock. At national level, relevant data to set the baseline metric score may also be available from a statistical analysis of the primary energy reported in the energy performance certificates (EPCs). However, caution should be exercised when using these values to verify the different end-uses accounted for and the gap when compared against actual energy demand.

Several studies have investigated possible primary energy demands that can be set as baseline metric scores and have proposed values to be used as benchmarks. However, there is no official standard or guideline in this dierection. Following the EU policies for climate change mitigation, a well-accepted best practice for the primary energy demand of buildings is the value that corresponds to an NZEB (representative values are reported in Table 6). Member States have developed NZEB definitions in line with national, regional, or local conditions in Table 6, including a numerical indicator of the primary energy use (expressed in kWh/m^2y). According to the recast EPBD (Directive, 2024), Member States shall set the maximum national thresholds for the energy demand of a zero-emission building or at least the NZEB value reduced by 10 %.

Table 6. NZEB benchmarks and targets depending on residential and non-residential buildings for different climate zone to set the baseline metric score.

Climate zone	**Building type**	**NZEBs benchmark**		**NZEB targets (kWh/m^2y)**
		Net primary use (kWh/m^2y)	**Total primary use (kWh/m^2y)**	
Mediterranean (e.g., Catania, Athens, Larnaca, Luga, Seville, Palermo)	Residential Non-residential	40-55 20-30	85-100 80-90	35-100 60-175
Oceanic (e.g., Paris, Amsterdam, Berlin, Brussels, Copenhagen,	Residential Non-residential	15-30 40-55	50-65 85-100	15-70 40-150
Continental (e.g., Budapest, Bratislava, Ljubljana, Milan, Vienna)	Residential Non-residential	20–40 40–55	50–70 85–100	20–125 25-125
Nordic (e.g., Stockholm, Helsinki, Riga, Stockholm, Gdansk, Tovarene)	Residential Non-residential	40–65 55–70	65–90 85–100	65–95 95–110

Source: Commission Recommendation, 2016.

Best practices of the EU-27 NZEB values for non-renewable annual primary energy per useful floor are reported in Table 7. The average annual primary energy in the EU-27 for new buildings is equal to 59 kWh/m^2year and 79 kWh/m^2year for residential and non-residential buildings, respectively. Similarly, the average annual primary energy in the EU-27 for existing buildings is equal to 71 kWh/m^2year and 97 kWh/m^2year for residential and non-residential buildings, respectively.

Table 7. NZEB energy performance levels in residential and non-residential, new and existing buildings in EU-27 Member States.

EU Member State and UK	NEW BUILDINGS Non-renewable primary energy (kwh/m²y)		EXISTING BUILDINGS Non-renewable primary energy (kWh/m²y)		Renewable Energy Sources	EPC
	Residential	Non-residential	Residential	Non-residential		
AT	41	84	68			
BE-BRU	45	85	55	100		
BE-FLA	20	30	20		15 kWh/m².y (residential), 20 kWh/m².y (non-residential)	
BE-WA	85	Relative requirement				A
BG	43	63	43	63	55%	A+
CY	75	94	75	94	25%	A
CZ	80	80				
DE	40	75	65			
DK	37	51				A 2015
EE	132	85	157	136		Energy Class A-B (new residential), A (new non-residential), C (existing)
EL	37	92	75	138	15–60% depending on building type	A for new, B+ for existing
ES	50	100				A for new, B+ for existing
FI	94	85	94	85		B
FR	60	110	100	150		
HR	28	21	28	21	30%	A+
IE	33	35	100	99 20% (new residential) A2 (new residential), A3 (new non-residential), B2 (existing residential)	20% (new residential)	A2 (new residential), A3 (new non-residential), B2 (existing residential)
IT	35	117	35	117	50%	
LT	60	80			50%	A++
LU	45	60	45	60		
LV	95	95	95	95		A
MT	56	176	56	176	25% residential 20% non-residential	
NL	30	28			30–50%	
PL	75	107.5	75	107.5		
PT	35	130	55	140	50% (residential) A	
RO	78	40	78	40	30%	
SE	90	70				A-C
SI	70	55	95	65	50%	A1, A2, or B1
SK	54	61	54	61		A0
UK	45	150				

Source: D'Agostino et al., 2021.

At **neighbourhood/urban scale**, the assessment boundary of the S.1.1 indicator is for all buildings in the designated project area following a similar evaluation used for the S.1.1 evaluation at building scale. However, dealing with large scale urban environments will encounter different types of buildings or mixed-use buildings, for which it may not be applicable to use the common indicator of the energy demand per useful floor area, as developed for the S.1.1 indicator at building scale. Hence, it may be more appropriate to normalise the energy demand per capita, as follows:

- Residential buildings can use the number of inhabitants.
- Tertiary buildings (e.g. gyms, swimming pools, museums, offices, hospitals) can use the number of users (e.g. customers, employees, visitors).
- Mixed residential and tertiary buildings can use the total number of inhabitants and users.

The normalisation of the energy demand per capita at neighbourhood or urban scale can rely on the number of inhabitants of the city. The permanent population of a city is assessed according to ISO 37120 (ISO, 2018).

The assessment of S.1.1 indicator at neighbourhood/urban scale starts with quantifying the total delivered energy demand by estimating the annual final consumption of thermal energy and electrical energy for building operations for all buildings in the neighbourhood/urban scale project. The indicator quantifies the delivered energy demand for each building and then sums it up for all buildings. The total sum of delivered energy demand for all buildings is then normalised with the number of inhabitants and users in the designated project area. There are also numerous ways for modelling yearly supplied energy at the city scale. The primary energy demand is finally determined by converting the different energy carriers to primary energy. For example (ISO, 2018), the total residential delivered electrical energy per capita shall be estimated as the total residential electricity use of a city in kilowatt-hours (numerator) divided by the total population of the city (denominator). The result shall be expressed as the total residential electricity use per capita in kilowatt hours/year. This may then be converted to primary energy demand, using the proper primary energy factor. The S.1.1 indicator at neighbourhood/urban scale assesses the improvement in primary energy demand for all buildings in the designated project area against a baseline metric score, which is the national or local baseline average of the annual primary energy demand per capita.

Spatial energy modelling at urban scale can be facilitated by the Geographic Information System (GIS), especially for analysing, storing, managing, and visualising big data using “top-down” (aggregate) and “bottom-up” (disaggregate) building energy models (Ali et al., 2021).. Urban-scale dynamic simulations are also available but are more complex, such as the city-level dynamic energy simulation and simulation tools can be used (e.g. CitySim, n.d.). Energy modelling approaches, for example, statistical regressions (Moghadam et al., 2018) and engineering archetypes (Moghadam et al., 2019) are applicable to model the final delivered energy demand for building stock.

3.4.3 Electricity peak demand (S.1.2)

At **building scale**, the *electricity peak demand (S.1.2)* indicator measures the electricity peak demand reduction in a building during its use stage against a baseline reference, requiring as an input the hourly electricity demand, expressed in kilowatt (kW) from which to derive the maximum electricity demand.

- For existing buildings, electricity power demand is commonly monitored on an hourly or quarterly basis for non-residential buildings and progressively for residential buildings as the installation of smart meters expands. It is increasingly becoming common to obtain this data from the records made available by the energy distributor.
- For new buildings or during design, hourly energy simulations can be used to conduct in-depth and predictive analyses of electricity power demand. Through detailed modelling of building characteristics, energy systems, climatic conditions, and user behaviour, it is possible to accurately determine the peak electricity demand. These data are crucial for planning and designing appropriate electrical systems and ensuring that the building operates efficiently from an energy perspective. Additionally, they allow designers to properly size the required equipment and electrical supply to meet the building's demand.

The evaluation of the S.1.2 indicator is carried out by considering as assessment boundary the building and all areas of the building in which electricity is used for building operations.

The S.1.2 score, which ranges between 0 and 100, is evaluated according to a three-step framework that consecutively estimate the scores of specific metrics to finally evaluate the indicator score, as follows:

1. *Maximum electrical power ($E_{p,max}$) recorded in the year of operation metric evaluation:* the hourly electric demand data of the examined building scale project needs to be analysed to determine the maximum electrical power in the year of analysis. Historical data demand for hourly electricity use may not be readily available, unless the building is equipped with a smart energy meter or a building management system. Alternatively, the maximum electrical power is indicated in the electricity contract and included in the utility bill, thus corresponding to the maximum power that can be supplied to the user. Relevant data can be obtained differently depending on newbuild or renovation projects, as follows:

   a) **Newbuild projects**, use simulations to estimate the necessary data. Use these values to identify the maximum.

   b) **Renovation projects** of existing buildings, these data can be obtained from the local energy distributor (as is the case in several European countries, e.g., Italy), typically provided at fifteen-minute intervals. Alternatively, the building must be equipped with smart meters that monitor instant electrical demand. In this case, the sum of the four measured values within the hour is used to obtain the energy (kWh) for that hour, and subsequently, power (kW).

   Start from the hourly electric energy demand data recorded in the year of analysis to identify the maximum value for all building services included in the energy performance assessment.

$$E_{P,max} = \max(E_{EPus,el,hour})_{year\ of\ analysis} \tag{11}$$

2. *Baseline ($T_{baseline}$) metric evaluation*: the evaluation carried out in step 1 needs to be repeated by using all historical hourly electrical demand data that precede the year of analysis considered in step 1, to identify the maximum electrical power (expressed in kW) from the historical data, according to Equation (12). In case these data are not available or relate to a historical period of less than one year, the baseline metric score corresponds to the maximum electrical power peak indicated in the electricity contract and included in the utility bill. This value corresponds to the maximum electrical power ($E_{P,max}$) that can be supplied to the building.

$$T_{baseline} = E_{P,max} = \max(E_P)_{historical\ data} \tag{12}$$

3. *S.1.2 score evaluation:* the S.1.2 score is estimated according to Equation (13), as a ratio in which the numerator is obtained by subtracting the score of the $E_{P,max}$ metric (evaluated in step 1) from the score of the baseline metric (evaluated in step 2) and the denominator is the score of the same the baseline metric. The ratio is multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.1.2 = \frac{T_{baseline} - E_{P,max}}{T_{baseline}} \cdot 100 \tag{13}$$

   The S.1.2 score indicates the extent to which the peak electricity demand recorded in the year of analysis varied from the baseline metric score. If the $E_{p,max}$ metric score is lower than the baseline metric score, S.1.2 results into a positive score, noting though that the maximum indicator score is 100. The higher the indicator positive score, the better the performance achieved, indicating a more significant reduction of the annual peak power demand than historical peaks. If the $E_{p,max}$ metric score exceeds the baseline metric score, leading the difference in the numerator to be negative, then the performance achieved is not sufficient and the S.1.2 indicator score is set equal to zero (0). Buildings should at least meet the minimum requirements for peak power demand.

The $T_{baseline}$ scores to be used in Equation (13) as baselines for peak electricity demand in buildings across Europe vary depending on national regulations, climate, and the use of electrical equipment and appliances. The variability in electricity demand among countries and within the same country makes challenging to establish relevant baselines. Each building should refer to its specific case and requirements when determining its peak electricity demand. The $T_{baseline}$ scores may vary depending on the specific contractual agreements with local utilities, building characteristics, and user requirements, especially for non-residential buildings, as reported in the following for Italy, Germany, and France:

— In Italy, the average maximum contractual peak is typically 3 kW, with the potential to increase to 6 kW in larger or high-demand residences.

— In Germany, the average maximum contractual peak is typically 3.7 kW (16 Amperes at 230 Volts), but it can be adjusted according to consumer needs.

— In France, residential buildings are typically supplied with 9 kVA, approximately equivalent to 9 kW.

At **neighbourhood/urban scale**, the *electricity peak demand (S.1.2)* indicator is not used.

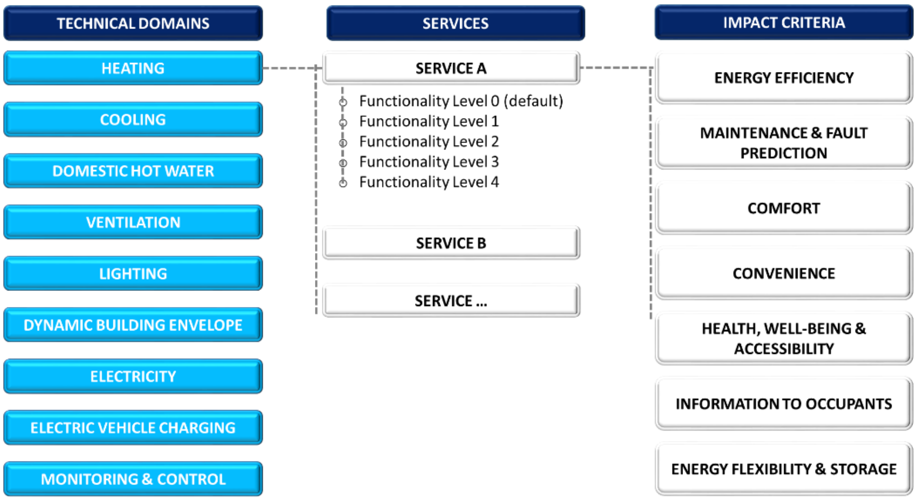
3.4.4 Smart readiness (building scale) or smart energy meters (neighbourhood/urban scale) (S.1.3)

At **building scale**, S.1.3 is evaluated based on the Smart Readiness Indicator (SRI) developed by the European Commission (Commission Delegated Regulation, 2020; Verbeke et al., 2020). The SRI aims to measure the capacity of a building to use smart-ready services. The 'smartness' of a building refers to its ability to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation to the operation of technical building systems, the external environment (including energy grids) and the demands from building occupants. The SRI assessment is carried out according to the common EU scheme for rating the smart readiness of buildings set into the Commission Delegated Regulation (2020) and relevant technical studies (Verbeke et al., 2020). Specifically, the SRI assessment consists of evaluating the performance of 'smart-ready services', which are included in a pre-defined 'smart-ready service catalogue', addressing nine technical domains (Figure 14): heating, cooling, domestic hot water, ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging, monitoring and control. The performance of each service is assessed against seven desired impacts of smart buildings: energy efficiency, maintenance and fault prediction, comfort, convenience, health, well-being and accessibility, information to occupants, energy flexibility and storage. The assessment is performed by selecting from a checklist the 'functionality level' that is relevant for every service. According to Verbeke et al. (2020), the SRI assessment may follow two main methods, as follows

— Method A - Simplified method, suitable for existing buildings or small non-residential buildings with low complexity and focused on the use of a simplified service catalogue that includes only 27 pre-defined services.

— Method B - Detailed method, suitable for new buildings and non-residential buildings that have a higher complexity and focussed on the use of a detailed service catalogue that includes 54 pre-defined services.

Figure 14. Overall structure of the Smart Readiness Indicator (SRI) service catalogue.



Source: Adapted from Verbeke et al., 2020.

The smartness of a building is assessed equally against three key functionalities, which are compounds of the seven impact criteria (Table 8). The overall SRI score of a building is determined by a weighted sum of its impacts for the above criteria across all the technical domains and then deriving the scores per key functionality, each of which is weighted equally for the overall SRI score.

Table 8. Key functionalities and the associated impact criteria for the SRI assessment.

Key functionality	Impact criteria
Optimise energy efficiency and overall in-use performance	Energy efficiency Maintenance and fault prediction
Adapt operation to the needs of the occupant	Comfort Convenience Health, well-being and accessibility Information to occupants
Adapt to signals from the grid (e.g. energy flexibility).	Energy flexibility and storage

Source: Data from Commission Delegated Regulation, 2020.

The SRI assessment of a building is facilitated through the use of an excel-based tool within the SRI assessment package provided by the European Commission[12] and more details are also available in the SRI training slides (European Commission, n.d.).

According to the SRI assessment (Commission Delegated Regulation, 2020), the S.1.3 score, which ranges from 0 (i.e. no smartness capability) to 100 (maximum smartness functionality), is evaluated based on a four-step framework that consecutively estimate the score of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Selection of smart-ready services for each technical domain*: the SRI rating depends on the ability of an examined building to facilitate 'smart-ready' services which are included in a 'smart-ready service catalogue', addressing the nine technical domains: heating; domestic hot water; cooling; ventilation; lighting; dynamic building envelope; electricity; electric vehicle charging; and monitoring and control. The full catalogue of SRI smart ready services contains a list of 54 services.

2. *Functionality level assessment*: for each service, 2 to 5 functionality levels are defined. A higher functionality level reflects a "smarter" implementation of the service, which generally provides more beneficial impacts to building users or to the grid compared to services implemented at a lower functionality level. The functionality levels are expressed as ordinal numbers, implying that ranks cannot be readily compared quantitatively from one service to another.

According to the Commission Delegated Regulation (2020), based on smart-ready services assessment and default or user-defined weighting factors at technical domain and impact criterion level, the smart readiness of a building can be expressed through the use of different aggregated smart readiness scores, expressed as a percentage. The aggregated scores may express smart readiness per (*i*) three key smart readiness functionalities (*f*); (*ii*) smart readiness impact criterion (*ic*), (*iii*) smart readiness technical domain (*d*), and (iv) total smart readiness. A total SR score indicates the overall smartness level of the building, while disaggregated scores allow the assessment of specific scores for the technical domains and impact categories. Details of the assessment are reported in the following step 3, according to Commission Delegated Regulation (2020).

3. *Smart readiness (SR) metric score evaluation*: the total SR score of a building is a percentage that expresses how close (or far) the building is to maximal smart readiness: the higher the percentage is, the smarter the building. The total SR score may be assessed as a weighted sum of the smart readiness scores of the three key functionalities, according to Equation (14). However, the total smart readiness score can be also obtained as a weighted aggregated sum of the scores of the seven impact categories.

$$SR = \sum W_f \cdot SR_f \tag{14}$$

where SR_f is the smart readiness score for key functionality f, W_f is the weight of key functionality f in the estimation of the total smart readiness scores, with $\Sigma W_f = 1$.

The smart readiness scores along the three key functionalities (SR_f) are evaluated according to Equation (15).

[12] https://ec.europa.eu/eusurvey/runner/SRI-assessment-package

$$SR_f = \sum_{ic=1}^{M} W_f\,(ic) \cdot SR_{ic} \tag{15}$$

where M is the total number of impact criteria, $W_f(ic)$ is the weighting factor expressed in percentage of impact criterion number ic for key functionality f, and SR_{ic} is the smart readiness score for impact criterion number ic.

The smart readiness score expressed as a percentage for each of the impact criterion (*SR_{ic})* are evaluated according to Equation (16).

$$SR_{ic} = \frac{\sum_{d=1}^{N} W_{d,ic} \cdot I(d,ic)}{\sum_{d=1}^{N} W_{d,ic} \cdot I_{max}\,(d,ic)} \cdot 100 \tag{16}$$

Where d is the technical domain in question, N is the total number of technical domains, $W_{d,ic}$ is the weighting factor expressed as a percentage of technical domain number d for impact criterion number ic, I (d,ic) is the score of technical domain number d for impact criterion number ic, and I_{max} (d,ic) is the maximum score of technical domain number d for impact criterion number ic,

The smart readiness scores of technical domains for each impact criterion ($SR_{d,ic}$) are estimated according to Equation (17).

$$SR_{d,ic} = \frac{I(d,ic)}{I_{max}(d,ic)} \cdot 100 \tag{17}$$

where I(d,ic) is the score of domain number d for impact criterion ic, and Imax(d,ic) is the maximum score of domain number d for impact c riterion number ic.

4. *S.1.3 score evaluation*: The S.1.3 score is estimated according to Equation (18) as a ratio in which the numerator is the difference between a baseline metric score and the *SR* metric (evaluated in step 4) and the denominator is the same baseline metric score. The ratio is multiplied by 100 so that the indicator score can be expressed as dimensionless value ranging from 0 to 100.

$$S.1.3 = \frac{(T_{baseline} - SR)}{T_{baseline}} \cdot 100 \tag{18}$$

where $SR_{d,ic}$ = Total SR score (%), $T_{baseline}$ = threshold assigned to the value minimum of the indicator which is the baseline building value (%).

If the *SR* metric score is lower than the baseline metric score, S.1.2 results into a positive score, noting though that the maximum indicator score is 100. The higher the positive score of the indicator, the greater the "smartness" of the building. If the $SR_{d,ic}$ metric score is greater than the baseline metric score, leading the difference in the numerator to be negative, S.1.3 results into a negative score indicating that the building performance does not satisfy the baseline metric. Hence, the S.1.3 score is set equal to zero (0). Buildings should at least meet the minimum requirements for smart readiness indicator.

Regarding the $T_{baseline}$ metric score to be used in Equation (18), detailed field data is not yet widely available to derive representative SRI scores, since the SR is currently emerging. However, Apostolopoulos et al. (2022) provided SRI scores for a small set of residential buildings differentiated in single- (SFH) and multi-family houses (MFH) in five EU countries and for the different scenarios and methods, as summarised in Table 9. This data may be used as the Tbaseline metric score. The study was designed to evaluate the retrofitting cost towards smartification for typical residential buildings. Initially the SR was estimated for a baseline scenario, i.e. the status of typical residential buildings. The baseline scenario represents buildings with the national minimum requirements in terms of energy performance (according to the relevant national EPBD legislation). Following the baseline scenario, two consecutive cycles of retrofitting towards two smartification scenarios (Scenario A and Scenario B) were considered aiming to increase the energy performance of buildings but mainly their smartness considering plug-and-play, cost efficient interventions. Buildings constructed after 2010 are considered energy efficient and thus the proposed retrofitting scenarios were limited to active systems without considering renovation of the building envelope. Specifically, the Scenario A considers market available technologies to help buildings move towards NZEBs, whereas the Scenario B integrates more technologies that move past NZEB that can contribute to classifying the buildings as PEBs. According to results, the minimum national requirements in compliance with the EPBD requirements (i.e. baseline scenario) for single-family houses lead to an average SRI score of 8 % and 5 % for Method A and B, respectively, whereas , the average SRI score is 7 % for multi-family houses for Method B. The SRI assessment of the baseline status in each of the five countris led to scores that range from 2 % to 9 % for single-family houses and from 4 % to 12 % for multi-family houses.

Table 9. Total SRI score and SRI class for residential buildings according to different scenarios and methods to set the baseline metric score.

Total SRI score (%) – SRI class (A-G)	**Baseline**		**Scenario A**		**Scenario B**	
	Method A	**Method B**	**Method A**	**Method B**	**Method A**	**Method B**
Single-family houses						
Denmark	7% (G)	7% (G)	37% (E)	32% (F)	70% (C)	68% (C)
Czech Republic	8% (G)	4% (G)	33% (F)	27% (F)	70% (C)	66% (C)
Greece	16% (G)	9% (G)	41% (E)	31% (F)	73% (C)	69% (C)
Bulgaria	4% (G)	2% (G)	28% (F)	26% (F)	66% (C)	64% (D)
Austria	5% (G)	4% (G)	29% (F)	23% (F)	68% (C)	67% (C)
Av. score (SFH)	8%	5%	34%	28%	70%	67%
Multi-family houses						
Denmark		8% (G)		30% (F)		65% (C)
Czech Republic		4% (G)		27% (F)		65% (C)
Greece		12% (G)		30% (F)		65% (C)
Bulgaria		5% (G)		24% (F)		60% (D)
Austria		5% (G)		27% (F)		69% (C)
Av. score (MFH)		7%		28%		65%

Source: Apostolopoulos et al., 2022.

Furthermore, the study from Apostolopoulos et al. (2022) highlighted that buildings that are constructed under the EPBD provisions, can increase smartness easier and at a relatively lower cost than older buildings. On average, buildings perform better in "Health, well-being and accessibility" and "Comfort" impact categories. Emphasis on improving the smartness of a building, such as building automation and control measures, can improve the overall performance to 65–80 % and perform better in improving energy efficiency towards NZEB. Finally, more emphasis should be given to solutions that could support interaction with the grid, especially considering the integration of renewables (see S.2.1 indicator) and energy storage (see S.2.2 indicator), towards energy net positive buildings.

At **neighbourhood/urban scale**, a different S.1.3 indicator is used. Specifically, the S.1.3 indicator at neighbourhood/urban scale refers to the percentage of buildings in the designated project area with smart energy meters, according to ISO 37122 (ISO, 2019). The metric of the share of buildings in a neighbourhood/urban area with smart energy meters shall be assessed as the ratio of the number of buildings in the designated project area with smart energy meters (N_{sm}) to the total number of buildings in the designated project area (N_t), expressed as percentage.

The indicator is evaluated according to Equation (19) as a ratio in which the numerator is the difference between the score of the metric referring to the share of buildings in a neighbourhood/urban area with smart energy meters and the baseline metric score ($T_{baseline}$) of the installed energy smart meters and the denominator is the same baseline metric score.

$$S.1.3 = \frac{\frac{N_{sm}}{N_t} - T_{baseline}}{T_{baseline}} \cdot 100 \qquad (19)$$

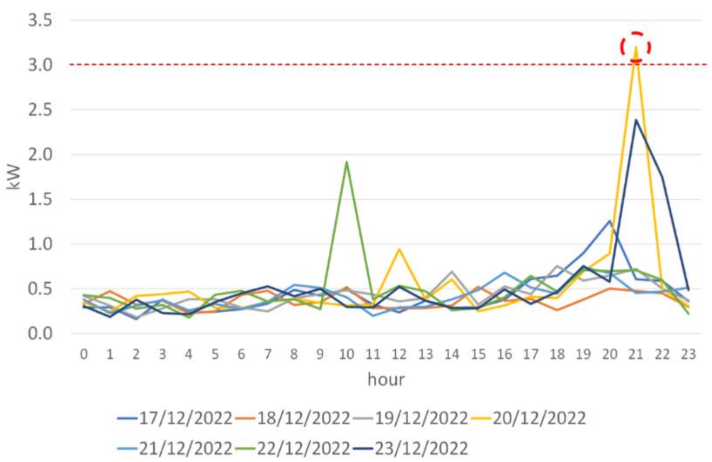
If the score of the metric (N_{sm}/Nt) is greater than the baseline metric score, S.1.2 results into a positive score, noting though that the maximum indicator score is 100. If the score of the metric (N_{sm}/N_t) is lower than than the baseline metric score, leading the difference in the numerator to be negative, S.1.3 results into a negative score indicating that the building performance does not satisfy the baseline metric. Hence, the S.1.3 score is set equal to zero (0). Neighbourhood and urban projects should at least meet the minimum requirements for the penetration of smart energy meters to facilitate the electrification and decarbonisation efforts of the European building stock.

Regarding the $T_{baseline}$ metric score that may be used in Equation (19), it is worth noting that the update and progress with smart energy meters has been slow in the EU-27, despite the legislative and regulatory frameworks that have been in place for several years. Furthermore, the lack of harmonised standards for energy meters may create additional delays with the certification of the meters. Sweden, Finland, Spain and Estonia have been leading the effort, reaching 100 % deployment of automated smart meters, and in many cases are already replacing the old units with modern and more flexible meters. Other countries like France, Germany and Ireland, have recently initiated the rollout of smart energy meters. The target is to reach European coverage by 2030. Currently, the penetration level of energy smart meters in the EU is estimated at 43 % that can be used as an average EU-27 baseline score (Tounquet and Alaton, 2020).

3.4.5 Example (S.1)

The example of the S.1 KPI evaluation is carried out by considering a **building scale project**, which is a new naturally ventilated multi-family residential building consisting of 22 dwellings for a useful internal floor area equal to 2700 m^2, located in Turin (Italy). The central space heating and domestic hot water (DHW) of the building are served by a natural gas fired non-condensing boiler, whereas the space cooling is served by local air-to-air heat pumps with indoor controls in each space. The metered annual energy consumption due to natural gas and electricity from the grid results into a value equal to 18351 m^3/year and 53360 kWh_e/year, respectively. The electricity use of a typical apartment within the building was monitored throughout 2022 and the hourly profile in Figure 15 corresponds to the week during which the electricity peak demand, equal to 3.2 kW, occurred, thus this value is considered representative to estimate the maximum electricity demand for the entire building.

Figure 15. Example (S.1): hourly profile of electricity demand.



Source: JRC.

The evaluation of the S.1 KPI at building scale to minimise the use of fossil fuels in the built environment depends on the scores of S.1.1, S.1.2 and S.1.3 indicators.

The **S.1.1 score** is evaluated according to the four-step framework, as reported in Section 3.4.2, to estimate the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Annual delivered energy demand (E_{del}) metric evaluation:* according to the standard ISO 52000-1 (ISO, 2017a), the building services included in the evaluation are heating, cooling, ventilation, humidification, dehumidification, and DHW. The building scale project does not foresee mechanical ventilation and dedicated humidification or dehumidification services. Following the breakdown of the total metered electricity (i.e. 53360 kWh_e/year) according to EN 16247-2 (CEN, 2022), the specific building services from electricity (i.e. cooling) account for 6 % of the total energy consumption due to electricity or 3202 kWh_e, while other uses like lighting, cooking, white appliances and plug loads account for 93 % or 50158 kWh_e. The annual delivered energy with the metered quantity of natural gas for heating and DHW is estimated

as the product of the annual quantity of natural gas delivered to the building (Q_{fuel}) by the lower heating value (LHV) of the natural gas, according to Equation (20):

$$E_{fuel} = Q_{fuel} \cdot LHV = 18351 \frac{m^3}{year} \cdot 9.45 \frac{kWh_{th}}{m^3} = 173417 \frac{kWh_{th}}{year} \quad (20)$$

The aim of step 1 is to quantify the delivered energy per energy carrier (i) allocated for the corresponding building services, as reported in Table 10.

Table 10. Annual delivered energy demand per energy carrier.

Energy Carrier	kWh/year	Building services	Primary energy factor [1]
Natural gas	173427	Heating, DHW	1.05
Electricity	3202	Cooling	2.42
Electricity	50158	Other (i.e. lighting, cooking, white appliances, plug loads)	

[1] PEF data retrieved from Ministry Decree 26/06/2015 (2015).

Source: JRC.

For sake of completeness, if the available utility energy data include other end-uses that are not part of the considered services (e.g. use of natural gas for cooking, use electricity for appliances and lighting), it will be necessary to estimate and allocate the energy for the different services. For example, the energy bills can be used during the off-heating season to determine the base loads for the use of natural gas for DHW and/or cooking, if applicable. This will be a first estimate, although there will be deviations on the energy use on an annual basis considering higher energy consumption for DHW in winter because of the lower water temperature.

Similar analysis must also be performed with the total electricity consumption from a utility meter to make the proper allocation of the total electricity to specific services considered in the methodological approach, i.e. exclude the energy used for lighting for residential buildings and appliances. The national household average annual consumption for appliances and lighting from the statistical analysis of Italian data provided by ENEA is 2072 kWh_e. This data consists of the energy use by refrigerator (299.1 kWh/year), horizontal freezer (83.4 kWh/year), dishwasher (170.0 kWh/year), washing mashing (220.8 kWh/year), PC (91.8 kWh/year), TV (235.84 kWh/year), hair dryer (281.3 kWh/year), electric oven (198.2 kWh/year), iron (149.6 kWh/year), vacuum cleaner (163.9 kWh/year) for a total of 1888.8 kWh/year and lighting equal to 183.2 kWh/year.

2. *Total annual delivered energy demand per useful floor area metric evaluation:* the annual delivered energy demand for the different energy carriers allocated for the corresponding building services is normalised for useful internal floor area, according to Equation 19 and 20 for natural gas used for hreating and DHW production, and electricity for cooling, reseptively.

$$\mathrm{E_{del,i,Au}} = \frac{173427}{2700} = 64.2 \frac{kWh_{th}}{m^2} \quad (i = natural\ gas) \quad (21)$$

$$\mathrm{E_{del,i,Au}} = \frac{3202}{2700} = 1.2 \frac{kWh_e}{m^2} \quad (i = electricity\ for\ cooling) \quad (22)$$

The annual delivered energy per electricity used for the other building services can also be nornalised for useful internal floor area, resulting into a value equal to 18.6 kWh_e/m^2.

3. *Total annual primary energy demand per useful floor area ($E_{pri,Au}$) metric evaluation:* The annual delivered energy per energy carrier evaluated in step 1 is transformed in primary energy demand by means of PEFs, according to the national values for Italy (reported in Table 10) by using Equation (8), as reported in Equation (9).

$$E_{pri} = \ (173427 \cdot 1.05) + (3202 \ \cdot 2.42) = \ 189142.7 \ \frac{kWh}{year} \tag{23}$$

Subsequently, the annual primary energy demand is assessed per unit floor area by using Equation (9), thus the annual primary energy demand per useful floor area metric results into a score equal to 70.05 kWh/m^{2}y, according to Equation 24.

$$E_{pri,Au} = \frac{189142.7}{2700} = 70.3 \ \frac{kWh}{m^2 year} \tag{24}$$

4. *S.1.1 score evaluation:* having estimated the metric, S.1.1 is evaluated in relation to the national context (Italy) considering that the building results into the climate zone E, as defined by the Italian decree on thermal energy systems (DPR, 1993). Each of the six climate zones defined in Italy, from the warmest (A) to the coldest (F) is characterised by a specific annual renewbale and non-renewable primary energy demand. An annual non-renewable primary energy demand equal to 221.1 kWh/m^2.year corresponds to the climate zone E, thus this value is set as the baseline metric score. Hence, the S.1.1 score is obtained by using Equation (10), leading to a score equal to 68.2 according to Equation (25).

$$S.1.1 = \frac{(221.1 - 70.3)}{221.1} \cdot 100 = \ 68.2 \tag{25}$$

The NZEB target for non-renewable primary energy in Italy is 35 kWh/m^2 (Table 6 and Table 7) and the best practice is equal to 22.3 kWh/m^2 per year (mean statistical primary energy demand value for the higher energy class A4). Apparently, there is room for improvement for the specific building, considering some additional energy efficiency measures to decrease the energy demand and use onsite renewables to cover part of the demand (see S.2.1 indicator).

The **S.1.2 score** is evaluated according to the four-step framework, as reported in Section 3.4.3, to estimate the scores of specific metrics to finally evaluate the indicator score, as follows:

1. *Maximum electric power ($E_{p,max}$) recorded in the year of operation metric evaluation:* according to data on the hourly electricity demand recorded in the year of analysis (i.e. 2022) for a typical dwelling in the new building (Figure 15), the maximum electrical power for the representative dwelling is identified by using Equation (11), as follows (Equation (26)).

$$E_{P,max} = \max\left(E_{EPus;el;hour}\right)_{2022} = 3.2 \ kW \tag{26}$$

   Based on this score, it is possible to estimate the maximum electrical power for the entire building, considering that the total number of dwellings within the building is 22. Hence, the maximum electrical power for the building is estimated equal to 70.4 kW.

2. *Baseline metric evaluation:* historical data are not available to estimate the baseline metric score, as the builing is new. Hence, the maximum electrical power in the electricity contract reported in the electricity bill is considered. Specifically, in Italy, the maximum peak for a dwelling in the electricity contract is typically 3 kW (red line in the demand profile identified in Figure 15) with the potential to increase to 6 kW in larger or high-demand dwellings. Based on this contractual data, the peak for the entire building ranges

from 66 to 132 kW. The score of the baseline metric related to the entire building is estimated equal to the average of the aforementioned two values, thus being equal to 99 kW.

3. *S.1.2 score evaluation:* based on the scores of $E_{P,max}$ (evaluated in step 1) and $T_{baseline}$ (evaluated in step 2), S.1.2 score is estimated using Equation (13), as follows (Equation (27)):

$$S.1.2 = \frac{(99 - 70.4)}{99} \cdot 100 = 28.9 \tag{27}$$

The S.1.2 indicator results into a positive score, thus indicating that the electricity peak demand of the building scale project analysed is lower than the baseline metric. However, a better score can be achieved if some improvement actions are considered. Examples in this direction refer to (i) increase user awareness but most importantly smart controls, that are critical in reducing the simultaneous use of high-consumption devices, (ii) enhance energy efficiency that is a priority and plays an important role for reducing peak electricity demand, among others for electrical appliances, equipment and other services, and (iii) in the context of building electrification, replacing gas-fired boilers and switching to heat pumps, or using induction plates for cooking, energy efficiency becomes crucial.

The **S.1.3 score** is evaluated according to the four-step framework, as reported in Section 3.4.4, to estimate the scores of specific metrics to finally evaluate the indicator score, as follows:

1. *Selection of smart-ready services for each technical domain*: Method A is usually sufficient for residential buildings. However, Method B that is mainly orientated for more complex non-residential buildings can be also used since it provides a higher level of information for the examined smart-ready services. The assessment used the default factors for the multicriteria evaluation. A smart-ready service catalogue is available that contains a list of 54 potential services to address 7 out of 9 technical domains for the specific building example: heating, DHW, cooling, lighting, dynamic building envelope, electricity, and monitoring and control. Some smart ready services for the specific building example include heat emission control, control of DHW storage charging, cooling emission control, window solar shading control, reporting information regarding local electricity generation.
2. *Functionality level assessment*: each service is assessed by selecting the relevant functionality level.
3. *Smart readiness (SR) metric score evaluation*: a total impact score is estimated for each impact criterion as a weighted impact sum for all the domain impact scores. The result is aggregated for the different impact criteria for the three key functionalities, using Equation (14). The overall SR score of the building is estimated at 12 %.
4. *S.1.3 score evaluation*: the baseline metric score is set at 7 %, according to the average SRI score for multi-family apartment buildings referring to a few EU countries (Table 9), according to Apostolopoulos et al. (2022). Thus, the S.1.3 score is evaluated by using Equation (18) and resulting into a value equal to 71.4, as reported in Equation (28).

$$S.1.3 = \frac{(12\,\% - 7\,\%)}{7\,\%} \cdot 100 = 71.4 \tag{28}$$

Having evaluated the scores of S.1.1, S.1.2, and S.1.3 indicators, the **S.1 score** is evaluated by using Equation (6) and considering the indicator weights corresponding to the combination of the project classification as building scale, newbuild type, and residential main use (Table 5). Hence, the S.1 KPI results into a score estimated equal to 51.3 that corresponds to the *Good* performance class (Figure 12, newbuild/residential), as reported in Table 11.

Table 11. Example of S.1 evaluation (building scale).

Indicator	**S.1.1**	**S.1.2**	**S.1.3**
Indicator score	68.2	28.9	71.4
S.1 score	0.3 • 68.2 + 0.45 • 28.9 + 0.25 • 71.4 = 51.3		
S.1 performance class	Good		
S.1 performance class score ($PCS_{S.1}$)	70		

Source: JRC.

Based on the indicator scores, S.1 score can be increased to attain the Excellentperformance class by placing more emphasis on reducing the electricity peak load, considering the relatively low score of S.1.2 indicator and the relatively high indicator weight. This is understandable considering the importance that peak electricity demand will play as buildings move to the electrification era, mandating very careful consideration of loads on the grid.

3.5 Maximise the use of sustainable energy in the built environment (S.2)

3.5.1 Description and assessment

At **building scale**, *maximise the use of sustainable energy in the built environment (S.2)* KPI is assessed through the following two indicators:

— *Share of renewables (S.2.1).*

— *Energy storage (S.2.2).*

S.2 score at building scale is evaluated according to Equation (29) using different indicator weights ($w_{S.2.j}$) depending on the different combinations of the project classification according to type (i.e. newbuild or renovation)/main use (i.e. residential or non-residential) of a building scale project, as reported in Table 5. It is worth noting that the denominator of Equation (29) equals unity for each combination. As example, the indicator weights within Equation (29) correspond to the combination of the project classification according to scale, type, and main use into building, newbuild, and residential, respectively.

$$S.2 = \sum_{j=1}^{2} \left(w_{S.2.j} \cdot S.2.j \right) \Big/ \sum_{j=1}^{2} \left(w_{S.2.j} \right) = 0.35 \cdot S.2.1 + 0.65 \cdot S.2.2 \tag{29}$$

The S.2 thresholds to associate the KPI score to the KPI performance class, at building scale, are illustrated in Figure 16, differentiating by building type and main use.

Figure 16. S.2 performance classes and thresholds (building scale).

Performance class:		Low	Acceptable	Good	Excellent	
S.2 thresholds ($t_{S.2}$):	$0 \leq$	$t_{S.2, Acceptable}$	$t_{S.2, Good}$	$t_{S.2, Excellent}$		≤ 100
Newbuild - Residential		≥ 25	≥ 50	≥ 75		
Newbuild - Non-residential		≥ 20	≥ 45	≥ 65		
Renovation - Residential		≥ 20	≥ 45	≥ 70		
Renovation - Non-residential		≥ 15	≥ 50	≥ 60		

Source: JRC.

At **neighbourhood or urban scale**, *maximise the use of sustainable energy in the built environment (S.2)* KPI is assessed thorugh the same two indicators considered at building scale. S.2 score at neighbourhood/urban scale is evaluated according to Equation (30) using different indicator weights ($w_{S.2.j}$) corresponding to the different combinations of the project classification according to type (i.e. newbuild or renovation)/main use (i.e. residential or non-residential) of a neighbourhood/urban scale project, as reported in Table 5. It is worth noting that the denominator of Equation (30) equals unity for each combination. As example, the indicator weights within Equation (30) correspond to the combination of the project classification according to scale, type, and main use into building, renovation, and residential, respectively.

$$S.2 = \sum_{j=1}^{2} \left(w_{S.2.j} \cdot S.2.j \right) \Big/ \sum_{j=1}^{2} \left(w_{S.2.j} \right) = 0.65 \cdot S.2.1 + 0.35 \cdot S.2.2 \tag{30}$$

The S.2 thresholds to associate the KPI score to the KPI performance class, at neighbourhood or urban scale, are illustrated in Figure 17.

Figure 17. S.2 performance classes and thresholds (neighbourhood and urban scale).

Performance class:	Low	Acceptable	Good	Excellent	
S.2 thresholds ($t_{S.2}$):	0 ≤	$t_{S.2, Acceptable}$	$t_{S.2, Good}$	$t_{S.2, Excellent}$	≤ 100
Newbuild - Residential		≥ 40	≥ 60	≥ 85	
Newbuild - Non-residential		≥ 35	≥ 55	≥ 80	
Renovation - Residential		≥ 20	≥ 50	≥ 75	
Renovation - Non-residential		≥ 15	≥ 45	≥ 70	

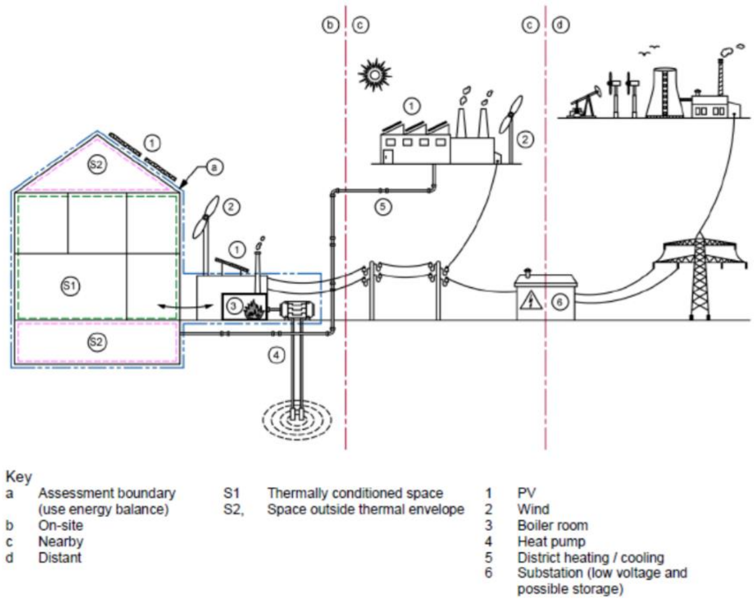
Source: JRC.

The S.2 KPI and its two corresponding indicators can be generally implemented in the self-assessment of any project irrespective of its scale/type/main use. However, the building-integration of energy systems based on renewable sources should carefully consider the aesthetic aspects of a building project and preserve its architectural features. Special care should also be exercised with cultural heritage buildings since minimum requirements in relevant energy-related EU directive (e.g. theEPBD) may allow EU Member States to exclude cultural heritage from the use of renewables in their national codes/regulations. Nevertheless, opportunities and technology solutions to properly integrate renewables in historic buildings and heritage areas (e.g. Roman-style photovoltaic roof tiles) can also be considered, carefully evaluating the feasibility of potential interventions case by case.

3.5.2 Share of renewables (S.2.1)

At **building scale**, the S.2.1 indicator is assessed based on Level(s) indicator 1.1 (Dodd et al., 2021b) to take into account the benefits of generating renewable energy to satisfy the primary energy demand, according to the following standards at international level: ISO 52000-1 (ISO, 2017a), ISO 52003-1 (ISO, 2017b), ISO 52010-1 (ISO, 2017c), ISO 52016-1 (ISO, 2017d), and ISO 52018-1 (ISO, 2017e). The indicator takes into account both the building thermal and electrical delivered energy demand, as well as the quantity of generated thermal and electrical energy from renewable sources. The delivered energy demand can be monitored using metered data, common for existing buildings to be renovated, or estimated data, common for new buildings. The S.2.1 score evaluation identifies the percentage of renewable energy sources within the comprehensive energy mixture, covering both thermal and electrical components (on-site, nearby, and distant) according to ISO 52000-1 (ISO, 2017a), as illustrated in Figure 18.

Figure 18. Schematic concept of assessment boundaries.



Source: Dodd et al., 2021b.

The underlying assessment method is based on ISO 52000-1 (ISO, 2017a) and ISO 52016-3 (ISO, 2023). Procedures on the energy from renewable energy sources related to different technologies (thermal solar systems, heat pumps, etc.) are given in the related sub-system EPBD standards.

The building assessment boundary includes all areas of the building in which useful thermal energy or electricity is used or produced. This boundary may not coincide with the physical boundary of the building (e.g., if a part of the technological system is located outside the building but constitutes part of the energy uses considered, it is considered included in the assessment boundary of the building).

The S.2.1 score, which ranges between 0 and 100, is assessed according to a four-step framework that consecutively estimates the scores of specifc sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Annual delivered energy demand ($E_{P,tot}$) sub-metric evaluation:* the annual delivered energy demand (for all forms of energy expressed in kWh/year), accounting for the annual total delivered energy for electricity (E_c) and for thermal energy *(Q_c),* is evaluated according to the same procedure indicated in the step 1 for the evaluation of the S.1.1 indicator (Section 3.4.2). Three main shares of energy are considered: (*i*) on-site energy (E_p for electricity and Q_p for thermal energy), that is the energy produced by on-site plants, (*ii*) exported energy (E_e for electricity and Q_e for thermal energy*)*, that is the share of energy produced on-site and not used, thus exported for each renewable energy generator, and (*iii*) imported energy (E_i for electricity and Q_i for thermal energy), that is the amount of energy from renewable sources delivered by distant/nearby generators into the assessment boundary, e.g. district heating, electricity grid. Specifically, the annual total delivered energy demand for electricity and thermal energy are calculated according to Equation (31) and (32), respectively. Estimated energy data are preferable for new buildings, while metered energy data are more appropriate for existing buildings to be renovated.

$$E_c = E_p - E_e + E_i \tag{31}$$

$$Q_c = Q_p - Q_e + Q_i \tag{32}$$

2. *Annual delivered energy demand for building operations covered by renewable energy sources ($E_{RES,tot}$) sub-metric evaluation:* all renewable energy[13] generators within the assessment boundary need to be identified to subsequently determine the three main shares of energy (expressed in kWh/year) for electrical *(E_{RES})* and thermal energy *(Q_{RES})*: (*i*) on-site energy (E_p for electricity and Q_p for thermal energy), that is the energy produced by on-site plants, (*ii*) exported energy (E_e for electricity *and* Q_e for thermal energy), that is the share of energy produced on-site and not used, thus exported for each renewable energy generator, and (*iii*) imported energy (E_i for electricity *and* Q_i for thermal energy), that is the amount of energy from renewable sources delivered by distant/nearby generators into the assessment boundary, e.g. district heating, electricity grid. Subsequently, the difference between the energy produced (on-site) and exported (nearby and distant) needs to be added to the delivered energy by nearby/distant renewable generators (imported). The result is the annual total delivered energy demand for building operations from renewable energy sources, according to Equation (33) and (34) for the electrical and thermal energy, respectively.

$$E_{RES} = E_p - E_e + E_i \tag{33}$$

$$Q_{RES} = Q_p - Q_e + Q_i \tag{34}$$

   Similarly to the step 1, estimated energy data are preferable for newbuild projects, whereas metered energy data are more appropriate for renovation projects of existing buildings, as follows:

   a) **Newbuild project:** energy flows need to be estimated by quantifying (*i*) the annual renewable energy by on-site generation components (i.e. on-site energy flows); and (*ii*) the annual delivered energy from

[13] According to the Renewable Energy Directive (Directive, 2023b), renewable energy sources means energy from renewable non-fossil sources, encompassing wind, solar (solar thermal and solar photovoltaic), geothermal energy, hydrothermal, osmotic energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogases.

nearby and distant energy renewable generators (i.e. imported energy flows), according to ISO 52000-1 (ISO, 2017a).

Regarding the on-site energy flows, the annual on-site renewable energy production for generated electrical and thermal energy from PV, wind, CHP and others is estimated, according to EN 15316-4-3 (CEN, 2017c). The assessment considers the time mismatch between the production and use of electricity (Table B.32 in ISO 52000-1 (ISO, 2017a)) to account for the time lag between electricity production and use and facilitates the breakdown of energy demand from renewable sources.

Regarding the imported energy flows, the imported electrical and thermal energy produced from all renewable sources may account from nearby and distant production sites for the specific building services. However, according to ISO 52000-1 (ISO, 2017a), the energy produced at a distant location and delivered to the building should not be considered in the renewable energy count. On the other hand, it is imperative to account for remotely generated renewable energy due to the growth of large-scale renewable installations, e.g. wind and photovoltaics, alongside the emergence of distributed renewable installations and local energy communities.

b) **Renovation project:** energy flows need to be measured by quantifying the annual renewable energy using actual operating data from (*i*) the total annual energy imported (electricity and heat bills) (i.e. imported energy flows), and (*ii*) the total annual energy produced by all on-site generators (i.e. on-site energy flows) reduced by the annual energy that is not used at the building site (i.e. exported energy flows). When data are extracted from energy bills, the method of energy demand breakdown is detailed in S.1.1.

As a result of the time mismatch between renewable energy production and building energy demand there is a need to support the installations with electrical and thermal energy storage (also refer to S.1.2). According to ISO 52000-1 (ISO, 2017a), the storage-weighted contribution is accounted as an auxiliary and it is added to the generator-weighted energy. Given that thermal and electrical storage systems are primarily powered by renewable energy sources during the charging phase, it is reasonable to consider the energy released by these systems as a contribution to renewable energy. This feature makes them significant contributors to clean energy when providing power in response to demand.

Using an energy storage system onsite, can reduce the exported energy from the building that is stored and used at a later time, thus reducing the imported energy. Estimated energy storage is preferable for newbuild projects, whereas measured energy storage is more appropriate for renovation projects of existing buildings, as follows:

a) **Newbuild project:** the energy storage needs to be estimated, thus the storage can be considered as a common sub-system. The energy delivered to the building for heating use is obtained according to EN 15316–5 (CEN, 2017d), whereas the energy delivered to the building for cooling is estimated according to EN 16798-15 (CEN, 2017e) and EN 16798-16 (CEN, 2017f). The energy delivered by the storage systems is estimated according to the following steps: define the initial state of charge of the storage (in the case of thermal storage this means the temperature level); quantify the energy stored by the storage unit; quantify the energy supplied; state of charge of the storage after discharge; energy required for charging; energy losses.

b) **Renovation project:** the energy storage needs to be measured, thus the energy flows are monitored and tracked, in order to quantify the energy delivered and used for building services, whether this energy is from onsite renewables production and direct use or from storage.

3. *Renewable energy (RES_{tot}) metric evaluation*: the RES_{tot} metric evaluates the share of renewable energy to the annual total delivered energy demand for building operations. The metric is estimated as the ratio of the annual total delivered energy demand (including both electricity and thermal energy) for building operations covered by renewable energy sources ($E_{RES,tot}$) (evaluated in step 2) to the annual total delivered electricity and thermal energy demand ($E_{P,tot}$) (estimated in step 1), expressed as a percentage, according to Equation (35). The greater the metric score, a more sustainable total energy use, thus indicating a more environemental-friendly building that exhibits less dependency on non-renewable energy sources. Despite a high share of renewable energy, the energy efficiency and a lower energy demand of a building scale project remain key-priorities to ensure no energy-related waste.

$$RES_{tot} = \frac{E_{RES,tot}}{E_{P,tot}} \cdot 100 \ [\%] \quad (35)$$

4. *S.2.1 score evaluation*: S.2.1 score is estimated according to Equation (36), as a ratio in which the numerator is the difference of the RES_{tot} metric score (evaluated in step 3) against the score of a baseline metric ($T_{baseline}$) at the local/national or EU level, and the denominator is the score of the same baseline metric, multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100. The score of the baseline metric corresponds to the average share of renewable energy on the total final energy consumption (i.e. electricity, heating and cooling) of the national or EU building stock to which the building scale project belongs.

$$S.2.1 = \frac{RES_{tot} - T_{baseline}}{T_{baseline}} \cdot 100 \quad (36)$$

If the RES_{tot} metric score is greater than the $T_{baseline}$ metric score, S.2.1 results into a positive score that may also exceed 100 in the event of a net positive building, noting though that the maximum indictor score is set to 100. If RES_{tot} metric score is lower than the $T_{baseline}$ metric score, leading the difference in the numerator to be negative, S.2.1 results into a negative score indicating that the performance achieved does not satisty the baseline metric due to a lower proportion of renewbale enrgy integration and the indicator score is set to zero (0). Furthermore, when the RES_{tot} metric score is equal to zero, the building is completely supplied by fossil fuel. Buildings should at least meet the minimum requirements for the share of renewables. The score of the baseline metric to be used in Equation (36) varies depending on the national or EU context considered, although the share of renewable energy on the total final energy consumption (i.e. electricity, heating and cooling) of the national or EU building stock is not immediately provided in available databases or standards. At EU level, the current practice for the share of renewables on the final energy consumption for three sectors (i.e. transport, electricity, and heating and cooling) in EU-27 Member States is available from Eurostat (2023c), accounting for an EU average share of energy consumption from renewables for electricity generation and for heating and cooling in 2022 equal to about 41.2 % and 24.8 %, respectively. This data may be assumed as scores of the baseline metric.

On average, the use of renewables in buildings is about 23.5 % (Commission SWD, 2021). Another option to set the score of the baseline metric at EU level is to focus on best practice, considering that the EU target is to reach at least 49 % of energy consumption from renewable sources in the building sector by 2030 (Directive 2023b). This target is transposed into national legislation to derive national contributions according to the Renewable Energy Directive.

At **neighbourhood/urban scale**, the assessment boundary includes all the buildings within the area of the neighbourhood/urban scale project. Specifically, multiple building-scale assessments need to be performed by considering each building within the area of the neighbourhood/urban scale project and applying the same four-step framework defined for the evaluation of the S.2.1 score at single building scale to assess the annual total delivered energy demand from renewable energy sources of each builing. Depending on the selected project boundaries, may include on-site, nearby, and/or distant renewable energy generation. To compare different values of the indicator, the selected perimeter should be identified as a subscript, for example, on-site, nearby, distant. Subsequently, the S.2.1 score is estimated as the sum of the E_{res} scores (expressed in kWh/year) corresponding to the separate building scale assessments, normalised by the sum of the annual total delivered energy demand (expressed in kWh/year) of each building. Hence, the S.2.1 indicator at neighbourhood/urban scale is the ratio of the renewables used by all buildings to the total annual delivered energy demand of all buildings.

3.5.3 Energy storage (S.2.2)

Energy storage balances energy supply and demand, facilitating the total delivered energy demand (that is evaluated by the S.1.1 indicator). The energy consumption patterns, can be used to identify when excess energy should be stored during periods of low consumption and when stored energy should be discharged during peak demand that refers to the periods when energy demand reaches its highest levels, often due to factors like extreme weather, increased industrial activity, or high usage periods. During such peaks, the strain on the electrical grid can be immense, potentially leading to brownouts or blackouts. This is where energy storage systems come into play. Energy storage solutions store excess energy during low-demand periods and release it during peak demand. This does not only enhance grid reliability but also allows for the efficient useof renewable energy sources, which may generate surplus energy at times when demand is low. In essence, the relationship between energy storage and energy consumption is driven by the need to efficiently manage and optimise energy use, making it a key factor in sizing and implementing effective energy storage solutions. Energy storage systems are closely intertwined with renewable energy sources due to their ability to tackle the intermittent nature of renewables. These systems enable the storage of excess energy generated by renewables during favourable conditions and make it available when needed, ensuring a consistent and reliable energy supply. Energy storage plays a critical role by mitigating intermittency, optimising renewable energy utilization, and enhancing grid stability. However, energy storage may also be critical if different energy tariffs are used to mitigate the use of energy from the grid at periods with lower tariffs.

At **building scale**, the *energy storage (S.2.2)* indicator evaluates the difference between the contribution of energy storage technologies to the flexibility requirements of an energy system and the flexibility requirements without an energy storage system. The flexibility requirement (FR) is estimated over time in terms of residual loads of energy that may be stored to the average residual loads.

The S.2.2 score, which ranges between 0 and 100, is assessed according to a four-step framework that consecutively estimates the scores of specifc sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Flexibility requirements over the time period (FR^T) sub-metric evaluation*: the FR^T sub-metric quantifies the extent to which the actual energy demand deviates from the average demand over a specific time scale, providing a measure of the flexibility needed to accommodate these deviations and ensure a stable and reliable power supply. The flexibility requirements *(FR)* over the time period *(T)* are estimated by summing the positive differences between the residual load *(RL)* at each time step *(t),* i.e. RL_t, and the average residual load over all time steps (t) within T, i.e. $\overline{RL_t}$ (Koolen et al., 2023), according to Equation (37). Specifically, the residual load at each time step (RL_t) is estimated as the delivered energy demand minus the energy locally produced by the renewable energy sources for each time step.

$$FR^T = \sum_T \frac{1}{2} \sum_t |RL_t - \overline{RL_t}| \ [kWh] \tag{37}$$

2. *Contribution of the energy storage to the flexibility requirements ($FR^{T,es}$) sub-metric evaluation:* different technologies, such as dispatchable units, storage systems, interconnectors, and demand-side management technologies, can impact the flexibility requirements differently and have the ability to adjust generation flexibly to match residual demand. In the case of the S.2.2 indicator, the contribution of the energy storage is considered. The next generation supplied by the energy storage system is subtracted from the residual load curve. This assessment reveals the difference in flexibility requirements compared to the standard residual load curve, allowing to determine the unique contribution of the energy system. This process gives valuable insights into how energy storage systems can effectively address the dynamic flexibility needs of the energy system, considering its contributions to the deviation between actual and normal load curves at each time step. Accordingly, the correlation can be updated to evaluate the effectiveness of the energy storage technologies in meeting the changing demands of the power system, according to Equation (38) where $FR^{T,es}$represents the contribution of the energy storage to the flexibility requirements at a specific timescale T and EP_t^{es} is the energy supplied by the energy storage at time step t..

$$FR^{T,es} = \sum_T \frac{1}{2} \sum_t |RL_t - \overline{RL_t}| - \sum_T \frac{1}{2} \sum_t |(RL_t - EP_t^{es}) - (\overline{RL_t - EP_t^{es}})| \ [kWh] \tag{38}$$

$FR^{T,es}$ represents the amount of energy storage that can contribute to balancing the grid and meeting the changing demand. If $FR^{T,es}$ is positive, it means that the energy storage helps meet the flexibility requirements by providing additional flexibility. If $FR^{T,es}$ is negative, it means that other technologies alone are sufficient to meet the requirements, and energy storage might not be needed to the same extent.

3. *S.2.2 score evaluation:* the metric corresponding to the energy storage factor, which is the contribution of the energy storage to the flexibility requirements ($FR^{T,es}$) to the flexibility requirements of the system in case of absence of any energy storage system, is estimated as the ratio of $FR^{T,es}$ (quantified in step 2) to FR^{T} (quantified in step 1), expressed as a percentage. Subsequently, S.2.2 score is estimated according to Equation (39) as a ratio in which the numerator is the difference of the score of the aforementioned metric against the score of the baseline metric ($T_{baseline}$) for the flexibility requirements, and the denominator is the score of the same baseline metric. The ratio is multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100

$$S.2.2 = \frac{\frac{FR^{T,es}}{FR^{T}} - T_{baseline}}{T_{baseline}} \cdot 100 \tag{39}$$

The indicator quantifies the contribution of energy storage as a solution to reduce the flexibility requirements and facilitate the energy system. If the S.2.2 score is negative, an energy storage is not needed. If the S.2.2 score is positive, an energy storage system can reduce the flexibility requirements of the energy system.

The baseline metric score to be used as a benchmark for comparing the behaviour of different buildings, neighbourhoods, cities, and countries can be based on the flexibility requirements and energy storage power (Koolen et al., 2023), as summarised in Table 12.

Table 12. Flexibility requirements and energy storage power.

Flexibility Requirements		
	Current 2022	Future 2050
European Union	120 TWh	2200 TWh
Italy	25 TWh	160 TWh
Energy storage power		
	Current 2022	Future 2050
European Union	60 GW	600 GW

Source: Koolen et al., 2023.

At **neighbourhood/urban scale**, multiple building-scale assessments need to be performed by considering each building within the designated area and applying the same three-step framework defined for the evaluation of the S.2.2 score at the single building scale. Subsequently, the S.2.2 score at the neighbourhood/urban scale is estimated as a weighted average of the S.2.2 indicator scores corresponding to the separate building scale assessments.

3.5.4 Example (S.2)

The example for the evaluation of the S.2 KPI is carried out by considering two projects referring to a building and an urban scale project, respectively.

The **building scale project** is new naturally ventilated multifamily residential building with auseful internal floor area equal to 2700 m^3, located in Turin (Italy). The building is equipped with a photovoltaic (PV) system and solar thermal collectors for DHW and space preheating. The PV produces 55110 kWh_e/year and exports 23547 kWh_e/year to the electric grid, while the solar collectors generate a thermal output of 39375 kWh_{th}/year. The electrical energy produced by the PV and not used directly for the building energy uses is first stored in batteries. This considers the time mismatch between production and use of electricity depending on the building load variations. Matching factors of produced and used electricity are according to ISO 52000-1 (ISO, 2017a). If the storage is fully charged, the electric energy is exported. In addition, the building imports 58360 kWh_e/year from the electric grid and thermal energy for an annual natural gas consumption of 6422 m^3 that is only used for space heating and supplementary for DHW, for periods not covered by the solar thermal.

The evaluation of the S.2 KPI to maximise the use of sustainable energy in the built environment depends on the scores of S.2.1 and S.2.2 indicators.

The **S.2.1 score** is evaluated according to the four-step framework, as reported in Section 3.5.2, to estimate the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Annual delivered energy demand ($E_{P,tot}$) sub-metric evaluation:* the annual total delivered electricity for building operations (E_c) is the balance of the total annual electricity produced by all on-site plants (E_p) like from photovoltaics, the electric energy produced by all local plants that is exported (E_e) as it is not used by the building, and the imported electricity (E_i) from the grid. Hence, E_c is calculated by using Equation (31), according to Equation (40).

$$E_c = 55110 - 23547 + 58360 = 89923\ kWh_e/year \tag{40}$$

   The onsite solar thermal energy (Q_p) is used for building DHW and space preheating and the exported thermal energy (Q_e) is zero. The imported thermal energy (Q_i) is estimated as the product of the natural gas annual consumption with the lower heating value (LHV), according to Equation (41).

$$Q_i = Q_{fuel} \cdot LHV = 6422\ \frac{m^3}{year} \cdot 9.45 \frac{kWh_{th}}{m^3} = 60688\ \frac{kWh_{th}}{year} \tag{41}$$

   The annual total delivered thermal energy demand (Q_c) for building operations for all forms of energy, i.e. renewables and natural gas, is calculated by using Equation (32), accoding to Equation (42).

$$Q_c = 39375 - 0 + 60688 = 100063\ \frac{kWh_{th}}{year} \tag{42}$$

   Based on these results, the $E_{P,tot}$ sub-metric is estimated equal to the sum of E_c and Q_c, thus resulting into a value equal to 189986 kWh/year.

2. *Annual total delivered energy demand for building operations covered by renewable energy sources ($E_{RES,tot}$) metric evaluation*: considering the onsite renewable energy generation for electricity, the total annual delivered demand for building operations covered by renewables is the balance of the total annual electricity produced by all on-site plants (E_p), the exported electricity (E_e) not used by the building, and the imported electricity from renewable sources delivered by distant/nearby generators that is zero in this example. Hence, the E_{RES} for electricity is evaluated by using Equation (33), according to Equation (43).

$$E_{RES} = E_p - E_e + E_i = 55110 - 23547 - 0 = 31563\ kWh_e/year \tag{43}$$

   The onsite renewable energy generation for thermal energy includes the onsite thermal energy production from the solar collectors and used for building operations (i.e. DHW and space preheating), the exported energy that is zero for this building project and the imported thermal energy from renewable sources delivered by distant/nearby generators that is also zero for this building project. Hence, the Q_{RES} for thermal energy is evaluated by using Equation (34), according to Equation (44).

$$Q_{RES} = 39375 - 0 - 0 = 39375\ kWh_{th}/year \tag{44}$$

   Based on these results, the $E_{RES,tot}$ sub-metric is estimated equal to the sum of E_{RES} and $Q_{RES,}$ thus resulting into a value equal to 70938 kWh/year.

3. *Renewable energy (RES_{tot}) metric evaluation*: the share of the renewable energy (estimated in step 2) to the annual total delivered energy demand for building operations (evaluated in step 1) is estimated by using Equation (35). Specifically, the share of renewable energy to the total annual delivered electricity and thermal energy is evaluated separately, according to Equation (45) and (46), respectively.

$$RES_{tot,e} = \frac{E_{RES}}{E_c} \cdot 100 = \frac{31563}{89923} \cdot 100 = 35.1\ \% \tag{45}$$

$$RES_{tot,th} = \frac{Q_{RES}}{Q_c} \cdot 100 = \frac{39375}{100063} \cdot 100 = 39.4\ \% \tag{46}$$

The total share of renewable energy ($E_{RES,tot}$) to the annual total delivered energy demand ($E_{P,tot}$), including both electricity and thermal energy, for building operations is estimated by using Equation (35), as follows (Equation (47)):

$$RES_{tot} = \frac{70938}{189986} \cdot 100 = 37.3\ \% \tag{47}$$

4. *S.2.1 score evaluation:* having estimated the RES_{tot} metric, S.2.1 score is evaluated in relation to the EU context, considering the score of the baseline metric for the average use of renewable in EU buildings equal to 23.5 % (Commission SWD, 2021). Depending on available local or national data, it may be more appropriate to use different scores of the baseline metric for thermal and electrical energy. The S.2.1 score, considering togheter the use of renewables for electrical and thermal energy, is obtained by using Equation (36), as follows (Equation (48)):

$$S.2.1 = \frac{(37.3\ \% - 23.5\ \%)}{23.5\ \%} \cdot 100 = 58.7 \tag{48}$$

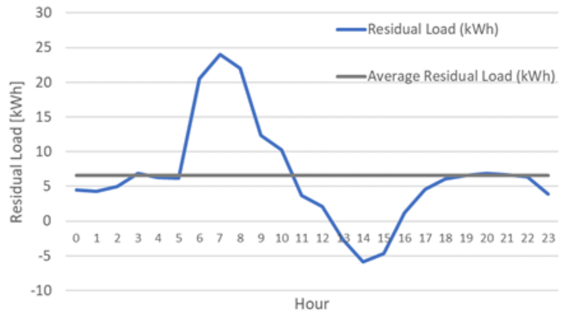
The S.2.1 score indicates that building scale project analysed accounts for an integration of the use of renewables exceeding the baseline metric of 58.7. However, further steps to improve the indicator performance relate to the replacement of gas-fired boiler with a heat pump, the use of solar thermal collectors and the heat-pump as a backup for DHW, and the use of green electricity from the main power supply to enhance the building environmental performance and minimise its carbon footprint.

The **S.2.2 score** is evaluated according to the three-step framework, as reported in Section 3.5.3, to estimate the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Flexibility requirements over the time period (FR^T) sub-metric evaluation*: the hourly energy profile of the PV performance during a typical spring day and the corresponding residual load and average residual load profiles are illustrated in Figure 19.

Figure 19. Example (S.2): hourly PV energy performance and residual load profile.

Hours	Delivered energy demand (kWh)	Energy produced by photovoltaics (kWh)	Daily Load RL_t (kWh)	Average Daily load $\overline{RL_t}$ (kWh)	Flexibility Requirements (kWh)
0	4.5	0.0	4.5	6.6	2.1
1	4.3	0.0	4.3	6.6	2.3
2	5.0	0.0	5.0	6.6	1.6
3	6.9	0.0	6.9	6.6	0.3
4	6.3	0.0	6.3	6.6	0.3
5	6.2	0.0	6.2	6.6	0.4
6	22.0	1.5	20.6	6.6	14.0
7	32.5	8.5	24.0	6.6	17.4
8	37.6	15.6	22.0	6.6	15.5
9	31.5	19.2	12.3	6.6	5.8
10	32.8	22.5	10.2	6.6	3.7
11	27.0	23.3	3.7	6.6	2.9
12	26.5	24.4	2.1	6.6	4.5
13	18.9	21.5	-2.6	6.6	9.2
14	11.3	17.1	-5.8	6.6	12.4
15	8.7	13.3	-4.7	6.6	11.2
16	6.6	5.4	1.2	6.6	5.4
17	5.1	0.5	4.6	6.6	1.9
18	6.1	0.0	6.1	6.6	0.5
19	6.6	0.0	6.6	6.6	0.0
20	6.9	0.0	6.9	6.6	0.3
21	6.7	0.0	6.7	6.6	0.1
22	6.4	0.0	6.4	6.6	0.1
23	4.0	0.0	4.0	6.6	2.6
	330.2	**172.8**	**157.3**	**157.3**	**114.3**



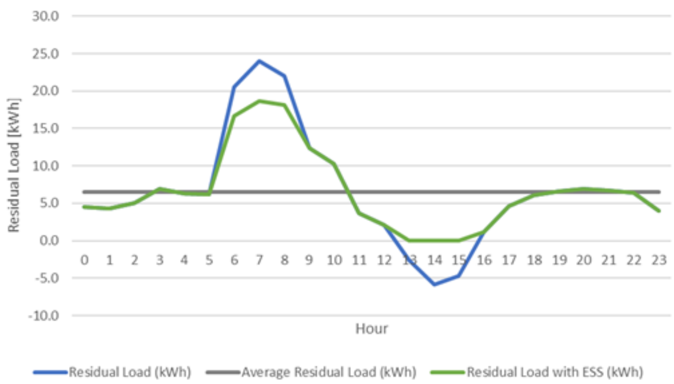
Source: JRC.

Having estimated the residual load and the average residual load, the daily FR^T sub-metric is evaluated by using Equation (37), as follows (Equation (49)).

$$FR^T = \frac{114.3\ kWh}{2} = 57.2\ kWh \tag{49}$$

2. *Contribution of the energy storage to the flexibility requirements*: the impact of an energy storage system (ESS) on hourly energy withdrawals from the grid is illustrates in Figure 20. It demonstrates that the withdrawal pattern deviates less from the daily average trend when energy storage is used, compared to the case without it.

Figure 20. Residual load profile with energy storage system.



Source: JRC.

The daily $FR^{T,es}$ sub-metric is evaluated by using Equation (38), as follows (Equation (50)):

$$FR^{T,es} = 57.2 - 44.05 = 13.1\ kWh \quad (50)$$

This represents the energy supplied by the ESS for one day. The influence of the energy storage system in respect to the system without energy storage can be calculated as the percentage of decreasing in the energy flexibility requirements.

3. *S.2.2 score evaluation:* having estimated the score of the FR^{T} *and* $FR^{T,es}$ sub-metrics and taking the baseline metric score for the energy storage factor as 15 %, S.2.2 is estimated by using Equation (39), as reported in Equation (51). Depending on available local or national data, it may be more appropriate to use different baseline metric scores.

$$S.2.2 = \frac{\left(\frac{13.1}{57.2} - 15\ \%\right)}{15\ \%} \cdot 100 = 52.7 \quad (51)$$

According to the evaluation of the S.2.2 score, it is pointed out that the contribution of the energy storage is positive, indicating that the energy storage system is reducing by 22.9 % the flexibility requirements of the system.

Having evaluated the scores of S.2.1 and S.2.2 indicators, **S.2 score** is estimated by using Equation (29) and considering the indicator weights corresponding to the combination of the project classification according to scale, type, and main use into building, newbuild, and residential, respectively (Table 5). Hence, S.2 results into a score estimated equal to 54.8 that corresponds to the *Good* performance class (Figure 16, newbuild/residential), as reported in Table 13. In the building decarbonisation era, eliminating the use of natural gas and on-site combustion, with heat pumps using green electricity would result to even higher performance class of S.2 indicator along with S.1 and S.3, among others.

Table 13. Example of S.2 evaluation (building scale).

Indicator	**S.2.1**	**S.2.2**
Indicator score	58.7	52.7
S.2 score	0.35 • 58.7 + 0.65 • 52.7 = 54.8	
S.2 performance class	Good	
S.2 performance class score ($PCS_{S.2}$)	70	

Source: JRC.

3.6 Minimise greenhouse gas emissions from the built environment (S.3)

3.6.1 Description and assessment

At **building scale**, *minimise greenhouse gas emissions from the built environment (S.3)* KPI assesses the Global Warming Potential (GWP) intended as the total amount of GHG emissions associated with the construction, operation, and demolition of a building during its entire lifecycle. This is closely related to a life cycle assessment (LCA), which is used to evaluate the environmental impacts of products, processes, or systems from cradle to grave, according to ISO 14040-44 (ISO, 2006a, b). S.3 is evaluated through the following two indicators:

— *Operational greenhouse gas (GHG) emissions (S.3.1).*

— *Embodied greenhouse gas (GHG) emissions (S.3.2).*

S.3 score is evaluated according to Equation (52) using different indicator weights ($w_{S.3,j}$) depending on the different combinations of the project classification according to type (i.e. newbuild or renovation)/main use (i.e. residential or non-residential) of a building scale project, as reported in Table 5. It is worth noting that the denominator of Equation (52) equals unity for each combination. As example, the indicator weights within Equation (52) correspond to the combination of the project classification according to scale, type, and main use into building, renovation, and residential, respectively.

$$S.3 = \sum_{j=1}^{2}(w_{S.3.j} \cdot S.3.j) \Big/ \sum_{j=1}^{2}(w_{S.3.j}) = 0.6 \cdot S.3.1 + 0.4 \cdot S.3.2 \quad (52)$$

The S.3 thresholds to associate the KPI score to the corresponding KPI performance class, at building scale, are illustrated in Figure 21.

Figure 21. S.3 performance classes and thresholds (building scale).

Performance class:	Low	Acceptable	Good	Excellent	
S.3 thresholds ($t_{S.3}$):	0 ≤	$t_{S.3,\ Acceptable}$	$t_{S.3,\ Good}$	$t_{S.3,\ Excellent}$	≤ 100
Newbuild - Residential		≥ 15	≥ 40	≥ 70	
Newbuild - Non-residential		≥ 15	≥ 40	≥ 70	
Renovation - Residential		≥ 10	≥ 35	≥ 65	
Renovation - Non-residential		≥ 10	≥ 35	≥ 65	

Source: JRC.

At **neighbourhood/urban scale**, *minimise greenhouse gas emissions from the built environment (S.3)* KPI is assessed through the following two indicators:

— *Operational greenhouse gas (GHG) emissions (S.3.1)* from all buildings within a neighbourhood/urban scale project.

— *Carbon sequestration (S.3.2)* that occurs in above-ground growing biomass, such as forestry and in below-ground soil.

S.3 score is evaluated according to Equation (53) by using different indicator weights ($w_{S.3.j}$) depending on the different combinations of the project classification according to type (i.e. newbuild or renovation)/main use (i.e. residential or non-residential) of a neighbourhood/urban scale project, as reported in Table 5. It is worth noting that the denominator of Equation (53) equals unity for each combination. As example, the indicator weights within Equation (53) refer to a project classified according to scale, type, and main use into neighbourhood, renovation, and residential, respectively.

$$S.3 = \sum_{j=1}^{2}(w_{S.3.j} \cdot S.3.j) \Big/ \sum_{j=1}^{2}(w_{S.3.j}) = 0.65 \cdot S.3.1 + 0.35 \cdot S.3.2 \quad (53)$$

The S.3 thresholds to associate the KPI score to the KPI performance class, at the neighbourhood/urban scale are illustrated in Figure 22.

Figure 22. S.3 performance classes and thresholds (neighbourhood/urban scale).

Performance class:	Low	Acceptable	Good	Excellent	
S.3 thresholds ($t_{S.3}$):	0 ≤	$t_{S.3,\ Acceptable}$	$t_{S.3,\ Good}$	$t_{S.3,\ Excellent}$	≤ 100
Newbuild - Residential		≥ 15	≥ 40	≥ 70	
Newbuild - Non-residential		≥ 15	≥ 40	≥ 70	
Renovation - Residential		≥ 10	≥ 35	≥ 65	
Renovation - Non-residential		≥ 10	≥ 35	≥ 65	

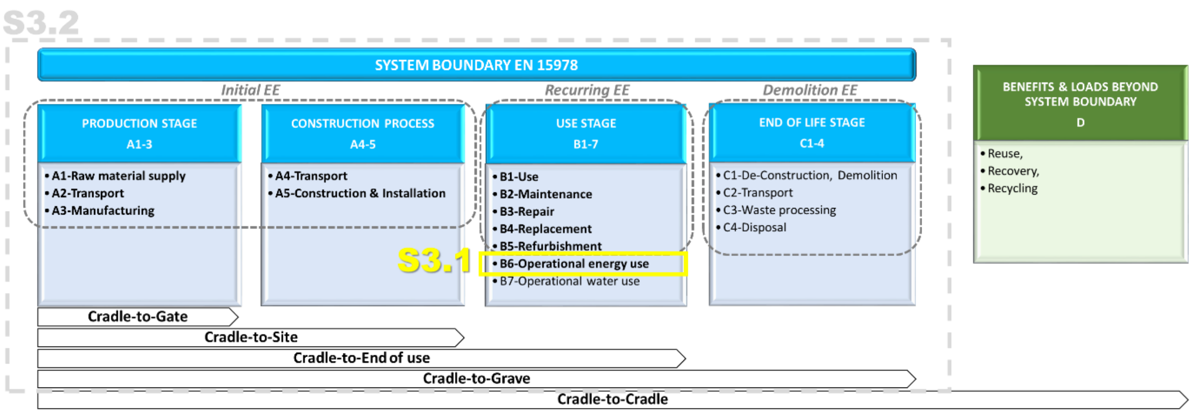
Source: JRC.

3.6.2 Operational greenhouse gas (GHG) emissions (S.3.1)

At **building scale**, the *operational greenhouse gas (GHG) emissions (S.3.1)* indicator is assessed based on Level(s) indicator 1.2 'Life cycle global warming potential' (Dodd et al., 2021c) that addresses emissions from all phases of the lifecycle of a building, encompassing both operational and embodied emissions, according to the European standards EN 15978 (CEN, 2011) and EN 15804 (CEN, 2012d).

The S.3.1 indicator is evaluated focusing on the use phase of the building life cycle, which corresponds to the module B6 "Operational energy use" of the standardised life cycle phases of a building (Figure 23), according to the European standard EN 15978 (CEN, 2011). Non-energy-related systems that contribute to GHG emissions, such as the provision of potable water, wastewater treatment or refrigerants leakage, are excluded from the scope.

Figure 23. Standardised life cycle stages (i.e. modules) of a building according to EN 15978 for S.3.1 evaluation.



Source: Adapted from CEN, 2011.

The S.3.1 indicator assesses the reduction of the annual operational GHG emissions of a building scale project, against a baseline metric score, corresponding to the average annual operational GHG emissions of the EU and/or national reference building stock, to evaluate the progress towards the performance of zero-emissions buildings.

The S.3.1 score, which ranges between 0 and 100, is evaluted according to a three-step framework that consecutively estimate the score of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Annual delivered energy (Q) sub-metric evaluation*: the delivered energy to be estimated (also refer to the S.1.1 evaluation in Section 3.4.2) is intended as the annual delivered energy, expressed per energy carrier (Q), supplied to the technical building systems, to satisfy the building uses taken into account. The energy is delivered to the building in the form of electricity, heat and fuel in order to satisfy the building services, according to ISO 52000-1 (ISO, 2017a). Additional building services can be integrated depending on the use of the building (e.g. office, retail, etc.) and quantified separately.

2. *Annual operational GHG emissions (annual OGHG) metric evaluation:* the *annual OGHG* metric is estimated by summing the products of the annual delivered energy per energy carrier (Q), estimated in step 1, by the corresponding GHG emission factors (k_{em}), and normalising the obtained sum per unit useful internal floor area (A_u), according to Equation (54). The GHG emissions factors are collected from national or transnational databases.

$$Annual\ OGHG = \frac{(Q_{el} \cdot k_{em,el}) + (Q_{dhc} \cdot k_{em,dhc}) + \sum_{i=1}^{n}(Q_{fuel,i} \cdot k_{em,i})}{A_u} \left[\frac{kgCO_2eq}{m^2year}\right] \quad (54)$$

The sub-metrics in Equation (54) are defined, as follows:

a) $Q_{fuel,i}$ is the total annual delivered energy from the i-th fuel (kWh_{th}) used for the building specific technical building systems (thermal energy of fossil fuels is estimated by multiplying the quantity of fuel by the lower heating value (LHV) of the fuel, also known as net calorific value, e.g. m^3 of natural gas is multiplied by the lower heating value equal to 9.45 kWh_{th}/m^3).

b) $k_{em,i}$ is the GHG emissions factor of the i-th fuel ($kgCO_2eq/kWh_{th}$),

c) Q_{el} is the total quantity of annual electrical energy from the grid (kWh_e),

d) k_{em} is the GHG emissions factor of the electrical energy from the grid ($kgCO_2eq/kWh_e$),

e) Q_{dhc} is the total quantity of annual energy from district heating/cooling (kWh_{th}),

f) $k_{em,dhc}$ is the GHG emissions factor of energy from district heating/cooling ($kgCO_2eq/kWh_{th}$),

The following values of GHG emission factors for different energy carriers (expressed in $kgCO_2eq/kWh$) can be considered (Lo Vullo et al., 2022): 0.202 (for natural gas), 0.268 (for oil), 0.007 (for solid biomass), 0.356 (for coal), 0 (from renewables). The value of GHG emission factor for the average EU-27 electricity is estimated equal to 0.258 $kgCO_2eq/kWh$ for 2022 (EEA, 2024c). Due to the high annual variability, the most recent GHG emissions factors for electricity in EU-27 should be used for future calculations (EEA, 2024c).

3. *S.3.1 score evaluation:* the S.3.1 score is assessed according to Equation (55) as a ratio, in which the numerator is the difference of the scores of a baseline metric ($T_{baseline}$) and the *annual OGHG* metric (evaluated in step 2) and the denominator is the score of the same baseline metric, multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100. The score of the baseline metric ($T_{baseline}$) corresponds to the average annual operational GHG emissions per unit floor area (expressed in $kgCO_2eq/m^2year$) of the national or EU building stock to which the building scale project belongs, according to building type and climatic zone.

$$S.3.1 = \frac{T_{baseline} - Annual\ OGHG}{T_{baseline}} \cdot 100 \tag{55}$$

If the *annual OGHG* metric score is lower than the $T_{baseline}$ metric score, S.3.1 results into a positive score. The higher the indicator score, the better the building performance related to the reduction of the operational GHG emissions, noting though that the indicator maximum score is 100. If the *annual OGHG* metric score is greater than the baseline metric score, leading the difference in the numerator to be negative, S.3.1 results into a negative score indicating that the building performance does not satisfy the baseline metric, providing an increase of the annual operational GHG emissions compared to the baseline metric, thus the indicator score is assumed equal to zero (0). Specifically, a building scale project with zero annual operational GHG emissions will obtain a S.3.1 score equal to 100, indicating a top performance (i.e. zero-emissions) building, whereas a baseline performance building will reach a S.3.1 score equal to 0. Buildings should at least meet the minimum requirements for GHG emissions. Based on the S.3.1 score, different scenarios to evaluate possible design improvements of a building scale project can be defined to obtain more effective reduction of operational GHG emissions.

The score of the baseline metric to be used in Equation (55) is determined as an average of the annual operational GHG emissions per unit floor area of the building stock, at national or EU level, to which the building belongs, according to Equation (56). The score of the baseline metric shall be specific per building use (e.g. residential, office, retail, etc.) and climate zone in which the building is located. In case of mixed-use buildings, the baseline metric score shall be estimated as the weighted average of the baseline annual operational GHG emissions of each occupancy considering their indoor useful area. In Equation (56), $T_{baseline,i}$ is the baseline annual operational GHG emissions of the *i-th* occupancy ($kgCO_2eq/m^2.year$) and $A_{u,i}$ is the internal useful floor area of the *i-th* occupancy *(m^2).*

$$T_{baseline} = \frac{\sum_{i=1}^{n} T_{baseline,i} \cdot A_{u,i}}{\sum_{i=1}^{n} A_{u,i}} \left[\frac{kgCO_2eq}{m^2year}\right] \tag{56}$$

The score of the baseline metric varies depending on the building stock considered at national or EU level, thus corresponding to the average annual operational GHG emissions of the national or EU building stock, respectively. If relevant data, at national and/or EU level, per building type or climate zone is not available, it is possible to use more generic and approximate data, reporting its source. The use of more accurate input data for the annual operational GHG emissions per building type and climate zone, will lead to a more accurate score of the indicator.

At EU level, representative scores of a baseline metric are summarised in Table 14. These scores are expressed as annual operational GHG emissions per unit floor area of building differentiated by high-rise, multi-family, and single-family building for three climate zones (Z) representative of South, Central, and North Europe, identified by specific HDD-ranges.

Table 14. Representative annual operational GHG emissions of buildings by climatic zone in Europe.

Climatic Zone	**High-rise buildings ($kgCO_2$ eq/m^{2}y)**	**Multi-family buildings ($kgCO_2$ eq/m^{2}y)**	**Single-family houses ($kgCO_2$ eq/m^{2}y)**
Z1: South Europe (564 to 2500 HDD)	18	30	65
Z2 Central Europe (2501 to 4000 HDD)	40	55	85
Z3: North Europe (4000 to 5823 HDD)	55	90	115

Source: data from Gervasio and Dimova, 2018.

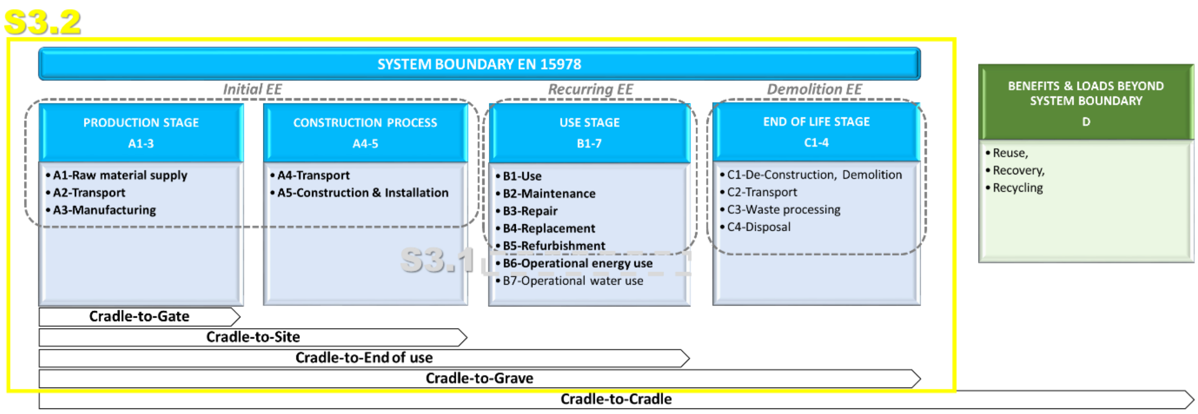
Furthermore, at EU level, it is possible to analyse the S.3.1 score in relation to the EU 2030 binding target, aimed at reducing the GHG emission by at least 55 %, compared to 1990 levels, towards the climate-neutrality by 2050, according to the European climate law (Regulation, 2021). Hence, a score of S.3.1, estimated by using the score of the baseline metric at EU level, being greater than 55 is considered as positive in relation to the EU 2030 target of GHG emission reduction.

At **neighbourhood/urban scale**, the operational GHG emissions assessment for a single building can be scaled up to assess the reduction of GHG emissions at a larger scale. Specifically, multiple building-scale assessments need to be performed by considering each building within the area of the neighbourhood/urban scale project and applying the same three-step framework defined for the evaluation of the S.3.1 score at single building scale to assess the annual operational GHG emissions of each building within the designated area. Subsequently, the S.3.1 score at neighbourhood and urban scale is estimated as the sum of the annual OGHG metric scores corresponding to the separate building scale assessments, normalised per inhabitant, according to ISO 37120 (ISO, 2018) and relevant guidelines (Covenant of Mayors, 2020) for reporting climate and energy. Hence, the S.3.1 score at neighbourhood/urban scale is expressed in tonnes CO_2-eq/inhabitant. Data on the number of inhabitants within the area of the neighbourhood/urban scale project can be collected from the statistical offices of municipalities. The score in tonnes CO_2-eq/inhabitant is then compared to a baseline metric score to obtain the S.3.1 score at neighbourhood/urban scale project, similar to the step 3 of the assessment framework for the S.3.1 evaluation at building scale. To help define the baseline metric score, the first total value of annual operational GHG emissions per inhabitant can be used as a baseline year to set emission reduction targets (e.g. 2030, 2050) and to monitor progress over time.

3.6.3 Embodied GHG emissions (building scale) or carbon sequestration (neighbourhood/urban scale) (S.3.2)

At **building scale**, the *embodied GHG emissions (S.3.2)* relies on the assessment of the overall GWP due to the emitted GHGs over a reference study period, generally corresponding to the service life of a common building (i.e. 50 years). The system boundary to carry out the analysis for the evaluation of S.3.2 indicator is "from cradle to grave", thus focusing on different stages of the lifecycle of a building scale project, including the production stage, the construction process, the use stage, and the end of life, corresponding to specific 'modules' of the standardised building lifecycle (Figure 24), according to EN 15978 (CEN, 2011) and elaborated by Level(s) indicator 1.2 (Dodd et al., 2021c). Specifically, the embodied GHG emissions in buildings are generated at the product and construction stage (i.e. modules A1-5), the use stage (i.e modules B1-5) and the end-of-life stage (i.e. modules C1-4). In the case of a new building scale project, the analysis to estimate the embodied GHG emissions focuses on A1-A5, B1, B4, B5, and C1-C4 modules, whereas B2 and B3 modules that refer to GHG emissions from the maintenance and repair of a building are not included in the system boundary due to issues related to data availability and data precision, also considering that these stages have a low carbon impact compared to other lifecycle stages. In the case of a renovation building scale project, the system boundary shall encompass all modules that relate to the extension of the building service life, namelyfrom B1 module onwards, as the stages relating to the original production (A1-3) and construction (A4-5) have already taken place. Hence, the GHG emissions associated with materials used in the construction process for the renovation shall be allocated to the use stage (B). Module D that concerns the benefits and loads arising from the reuse of products or the recycling or recovery of materials and compoenets is optional. If module D is included in the system boundary, the results shall be reported separately. In case of demolition of existing buildings on the site prior to the construction of a new building, the benefits and loads arising from the recovery of demolition shall be considered to be outside of the system boundary. The benefits and loads must therefore be eventually allocated to the previous building to avoid double counting.

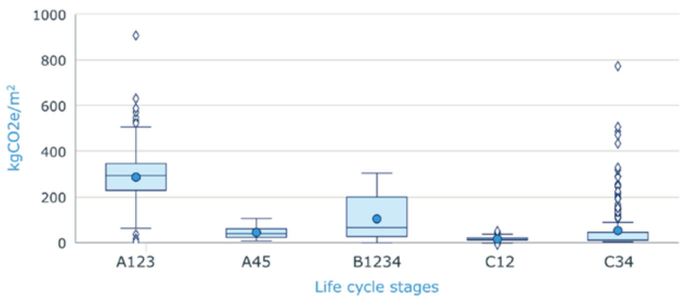
Figure 24. Standardised life cycle stages (i.e. modules) of a building according to EN 15978 for S.3.2 evaluation.



Source: Adapted from CEN, 2011.

The largest contribution of embodied GHG emissions in European buildings (Figure 25) occurs during the production stage (i.e. modules A1-3), with a mean value of about 300 kg CO_2eq/m^2, ranging from 70 to 520 kg CO_2eq/m^2 (Röck et al., 2022). The second largest contribution occurs during the use phase (i.e. modules B1-4), with a mean value of around 120 kgCO_2eq/m^2, which represents the total amount of embodied GHG emissions from cleaning, maintenance, and replacement activities taking place over a 50-year reference study period (Röck et al., 2022).

Figure 25. Embodied GHG emissions per unit floor area for different life cycle stages.



Source: Röck et al., 2022.

The S.3.2 indicator assesses the reduction of the embodied GHG emissions of a building scale project in reference to a baseline metric score, corresponding to the average embodied GHG emissions of the national and/or EU building stock. The assessment of the embodied GHG emissions of a building is a complex process, which shall be performed through the LCA methodology, according to ISO 14040-44 (ISO, 2006a, b), by using a robust LCA tool in compliance with the European standard EN 15978 (CEN, 2011). The assessment requires comprehensive data on construction products and environmental impacts over the entire lifecycle of the building.

The S.3.2 score, which ranges between 0 and 100, is evaluted according to a four-step framework that consecutively estimate the score of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Bill of Quantities (inventory) preparation*: the inventory of all construction products integrated in the building scale project, in the form of a Bill of Quantities (BoQ) needs to be prepared. The construction products and materials to be included in the inventory refer to building elements, components, technical installations, external works, etc., classified through different tiers, according to Level(s) indicator 2.1 'Bill of Quantities, materials and lifespans' (Donatello et al., 2021b), as listed in Table 15. In case of a renovation building scale project, only the new construction products added to the building shall be taken into consideration, thus excluding the existing ones. The inventory accounts for the bill of quantities of all construction products, used in a newbuild or renovation building scale project, that are included in the physical scope of the assessment. The system boundaries include the A1-A5, B1, B4, B5, and C1-C4 modules for a newbuild building scale project; whereas the the B1, B4, B5, B6, C1-C4 moduels are considered for a renovation building scale project.

Table 15. Classification of building elements and components for the bill of quantities preparation.

Tier 1	**Shell (substructure and superstructure)**		
Tier 2	Foundations (substructure)	**Tier 3**	Piles, basement, retaining walls
	Load bearing structural frame		Frame (beams, columns and slabs), upper floors, external walls, balconies
	Non-load bearing elements		Ground floor slab, internal walls, partitions and doors, stairs and ramps
	Façades		External wall systems, cladding and shading devices, façade openings (including windows and external doors), external paints, coatings and renders
	Roof		Structure, weatherproofing
	Parking facilities		Above ground and underground (within the curtilage of the building and servicing the building occupiers)
Tier 1	**Core (fittings, furnishings and services)**		
Tier 2	Fittings and furnishings	**Tier 3**	Sanitary fittings, cupboards, wardrobes and worktops (where provided in residential property), ceilings, wall and ceiling finishes, floor coverings and finishes
	In-built lighting system		Light fittings, control systems and sensors
	Energy system		Heating plant and distribution, cooling plant and distribution, electricity generation and distribution
	Ventilation system		Air handling units, ductwork and distribution
	Sanitary systems		Cold water distribution, hot water distribution, water treatment systems, drainage system
	Other systems		Lifts and escalators, firefighting installations, communication and security installations, telecoms and data installations
Tier 1	**External works**		
Tier 2	Utilities	**Tier 3**	Connections and diversions, substations and equipment
	Landscaping		Paving and other hard surfacing, fencing, railings and walls, drainage systems

Source: Adapted from Donatello et al., 2021b.

2. *GWP of construction products (GWP-total) sub-metric evaluation*: data concerning the environmental impacts in terms of total Global Warming Potential of all the construction products included in the inventory defined in step 1 need to be collected for the lifecycle stages included in the system boundary of the assessment. Relevant data on the GWP of construction products is available from the Environmental Product Declarations (EPDs) or in LCA databases. Depending on the type of construction product, the GWP-total values may be normalised per functional unit of the product, e.g. mass (kgCO_2eq/kg), volume (kgCO_2eq/m^3), area (kgCO_2eq/m^2), etc.

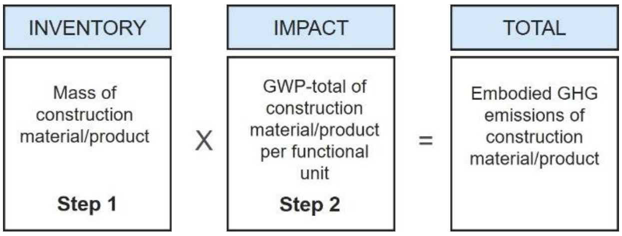
   Data concerning the GWP-total of construction products must be contextualised to the region where the building is located. In general, the GWP depends on the national energy mix that varies from country to country (e.g. different share of renewable energy, use of nuclear energy). For example, if the assessment is performed in Italy (with a national energy mix that is dominated by fossil fuels, i.e. 79 %, and no nuclear energy is used (European Commission, 2024)), it would not be appropriate to use a French LCA database (with a national energy mix that exhibits a prevalence, i.e. 42 % of nuclear energy (European Commission, 2024)). Other influencing factors that must be contextualised include the transport mode of materials (e.g. local, national, origin of imported materials). Accordingly, the degree of confidence in the results depends upon the quality of the data used. The following data hierarchy shall be used to prioritise data resources: (*i*) use of data from EPDs specific for the construction products used in the building; (*ii*) use of average data from EPDs describing average products and estimated using representative average data; (*iii*) use of average data from LCA databases that are compliant with the EN 15804 (CEN, 2012d). If the environmental data are from other sources which are not in compliance with EN 15804 (CEN, 2012d), the following minimum data quality requirements apply: (*i*) data shall have been checked for plausibility and compliance with the rules of EN 15804 (CEN, 2012d); (*ii*) data should be as current as possible with the last update not being older than 10 years for generic data and 5 years for manufacturer's data; (*iii*) datasets for estimations should be based on one-year averaged data, if relevant, and reasons for a different assessment period shall be listed; (*iv*) the technological processes associated with the product shall be representative of the declared product or product group; and (*v*) the technological processes shall be representative of the region where the production is located.

3. *Embodied GHG emissions of building ($EGHG_b$) metric evaluation:* the embodied GHG emissions of a building metric is estimated as the amount of embodied GHG emissions of the entire building scale project (i.e. *GWP-total*$_b$) normalised per its internal useful floor area (A_u), according to Equation (57).

$$EGHG_b = \frac{GWP\text{-}total_b}{A_u} \quad \left[\frac{kgCO_2eq}{m^2}\right] \tag{57}$$

The embodied GHG emissions of the building are estimated on the basis of the quantities of building products estimated in step 1 and the GWP-total values collected in step 2, according to the rationale provided in Figure 26. The assessment shall be carried out for a reference study period of 50 years, corresponding to the service life of a common building. However, the reference study period may differ from the required service life of the building.

Figure 26. Evaluation of embodied GHG emissions of each construction product in a building scale project.



Source: JRC.

The lifespan of building parts and elements, which is used to derive the times of replacement during the reference study period of 50 years, can be estimated in various ways: (*i*) according to the factor methodology in ISO 15686-8 (ISO, 2008), (*ii*) using data provided by manufacturers and suppliers, or (*iii*) using generic lifespans from LCA tools, building costing tools or other guidance for typical service lives listed in Level(s) indicator 2.1 'Bill of Quantities, materials and lifespans' (Donatello et al., 2021b).

4. *S.3.2 score evaluation:* the S.3.2 score is estimated according to Equation (58) as a ratio, in which the numerator is the difference of the score of a baseline metric ($T_{baseline}$) of embodied GHG emissions (expressed in kg CO_2-eq/m^2) and the score of the $EGHG_b$ metric (evaluated in step 3) and the denominator is the score of the same baseline metric ($T_{baseline}$), multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100.

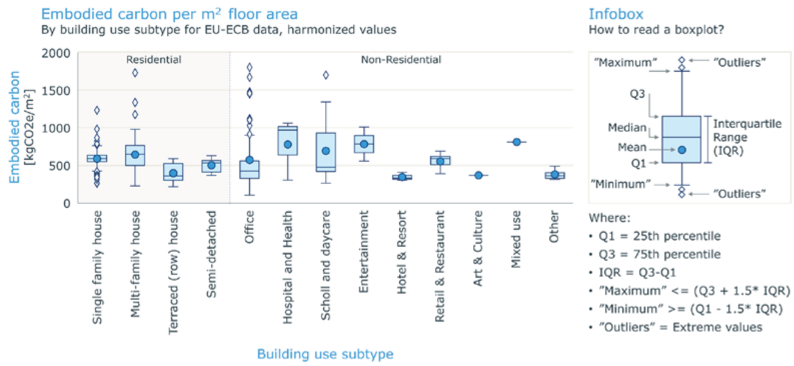
$$S.3.2 = \frac{(T_{baseline} - EGHG_b)}{T_{baseline}} \cdot 100 \quad (58)$$

If the $EGHG_b$ metric score is lower than the $T_{baseline}$ metric score, S.3.2 results into a positive score. The higher the indicator score, the better the building performance related to the reduction of embodied GHG emissions, noting though that the indicator maximum score is 100. If the $EGHG_b$ metric score is greater than the baseline metric score, leading the difference in the numerator to be negative, S.3.2 result into a negative score indicating that the performance does not satisfy the baseline metric, thus the indicator score is set to zero (0). Buildings should at least meet the minimum requirements for GHG emissions. The $EGHG_b$ metric is compared with the baseline metric score to evaluate the building performance related to its embodied GHG emissions. A very high performance building will have an S.3.2 score greater than 50, which implies a building with embodied GHG emissions that are less than half of the average embodied GHG emissions of the baseline EU or national building stock. Based on the S.3.2 score, different scenarios to evaluate possible design improvements of a building scale project can be defined to obtain more effective reduction of embodied GHG emissions.

The score of the baseline metric to be used in Equation (58) corresponds to an average of embodied GHG emissions per unit floor area of the national or EU building stock to which the building scale project belongs, according to building type (i.e. newbuild/renovation), main construction material, and use. Relevant studies in this direction provides data useful to set the score of a baseline metric of embodied GHG emissions per unit floor area for newbuild (Röck et al., 2022) and renovation (Brown et al., 2014; EASAC, 2021) projects, as follows:

— **Newbuild project** — Based on data from LCA studies in 769 buildings in Belgium, Denmark, Finland, France and the Netherlands, the following mean values of embodied GHG emissions per unit floor area are estimated for different building use (Figure 27) and main construction material, for a reference study of 50 years (Röck et al., 2022): residential buildings (550 $kgCO_2eq/m^2$), non-residential buildings (450 $kgCO_2eq/m^2$), massive concrete buildings (750 $kgCO_2eq/m^2$), massive brick buildings (700 $kgCO_2eq/m^2$), massive timber buildings (600 $kgCO_2eq/m^2$). Furthermore, based on the analysis of the contribution to the embodied GHG emissions from different building parts grouped in ground (basement and foundation), load-bearing, envelope, internal elements, technical services, and appliances, a major contribution stems from technical services, e.g. heating, cooling, domestic hot water and sewage systems, accounting for a mean value of embodied GHG emissions per unit floor area equal to 190 $kgCO_2eq/m^2$(Röck et al., 2022).

Figure 27. Harmonised full life cycle embodied GHG emissions per unit floor area for different building uses.



Source: Röck et al., 2022.

— **Renovation project** — According to EASAC (2021), various studies (e.g. Rasmussen et al., 2018; Moncaster et al., 2019; Ylmén et al., 2019; Lausselet et al., 2021) indicate that the embodied GHG emissions per square metre of floor area for new buildings lie between 250 and 400 $kgCO_2eq/m_2$. Depending on the nature and depth of the renovation works and the materials used, the same studies point out that the increase of embodied GHG emissions for a renovated building is typically less than 50 % of the embodied emissions for a new building (i.e. less than 125–200 $kgCO_2eq/m^2$). This figure may be much lower if the renovation aims to improved thermal insulation and heating or cooling systems, without major structural changes (Brown et al., 2014).

The S.3.2 indicator score can provide useful insights to develop life cycle scenarios that can support decision making processes during the design phase of carbon neutral buildings. Specifically, the indicator can be used to evaluate alternative scenarios to:

— Re-use materials/components of an existing building and its structure compared to its demolition and construction of a new building. This is a relevant scenario as the focus shifts from the performance of new buildings to large scale, deep renovation, according to the EU Renovation Wave (COM, 2020c).

— Define the best design strategy (e.g. building structure) to minimise the embodied GHG emissions of the building and meet carbon neutrality requirements. There are various solutions for reducing embodied GHG emissions in buildings, including synergies among various strategies on each of the three pillars of the sufficiency, efficiency, renewables (SER) framework (Cabeza et al., 2022). The following solutions and strategies can be considered: (*i*) implement material-efficiency when designing structural systems, (*ii*) use low-carbon building materials including bio-based materials (e.g. timber) and energy systems, (*iii*) consider occupational density and sufficiency principles in building design to reduce the building floor area and hence material consumption.

At **neighbourhood/urban scale**, the *carbon sequestration (S.3.2)* indicator focuses on carbon captured and stored in ecosystems on land to estimate the carbon stock and the carbon sequestration rate of ecosystems on land. The indicator is also useful to understand the extent of ecosystems on land in neighbourhood or urban scale projects contributing to the mitigation of GHG emissions, and evaluate the impact of changes in land uses. Captured and stored carbon is referred to as a "carbon pool" that includes living biomass (above and belowground) and soils (IPCC, 2019). The carbon stock is the quantity of carbon contained in a "pool", meaning a reservoir or system which has the capacity to accumulate or release carbon. The impact of changes in the carbon stock on GHG mitigation for climate protection is often referred to as carbon sink, although it could also act as a net source of emissions.

The S.3.2 score is evaluated accoridng to a three-step framework that consecutively estimates the scores of specific sub-metrics and metrics, to finally evaluate the indicator score, as follows:

1. *Inventory of ecosystems on land and area sub-metric evaluation:* an inventory of the different ecosystems on land types (e.g. grasslands, shrubs, sparsely vegetated, croplands, forests, wetlands, etc.) needs to be prepared by quantifying the extension of each *i*-th ecosystem on land type (i.e. $Area_i$, expressed in ha).

2. *Carbon stock (CS) metric evaluation*: carbon stock shall be estimated as the sum of products of the extension of the *i*-th ecosystem on land (i.e. $Area_i$, expressed in ha) by the CO_2 stock ratio of the *i*-th ecosystem on land (CSR_i, expressed in tCO_2/ha), according to Equation (59). Representative values of CO_2 stock ratio per the *i*-th ecosystem on land are reported in Table 16.

$$CS = \sum_{i=1}^{n} Area_i \cdot CSR_i \quad [tCO_2] \tag{59}$$

Table 16. Representative CO_2 stock ratios of various land ecosystems.

Ecosystem	CO_2 stock ratio (tCO_2/ha)
Cropland	363
Forest	424
Grassland	18
Shrub	44
Sparsely vegetated	88
Wetland	907

Source: based on Hendriks et al., 2022.

3. *Annual carbon sequestration (CSEQ) in ecosystems metric evaluation:* the annual carbon sequestration is estimated as the sum of products of extension of the *i-th* ecosystem on land (i.e. $Area_i$, expressed in ha) by their annual CO_2 sequestration rates (i.e. $CSRa_i$, expressed in *tCO_2/ha year*), according to Equation (60).

Representative values of annual CO_2 sequestration rate per the *i*-th ecosystem on land are reported in Table 17.

$$CSEQ = \sum_{i=1}^{n} Area_i \cdot CSRa_i \quad \left[\frac{tCO_2}{year}\right] \tag{60}$$

Table 17. Representative annual CO_2 sequestration rates of various land ecosystems.

Ecosystem	**Annual CO_2 sequestration rate (tCO_2/ha y)**
Cropland	3.3
Forest	11.0
Grassland	0.9
Shrub	0.6
Sparsely vegetated	0.1
Urban trees	8.1
Wetland	0.1

Source: based on Hendriks et al., 2022.

4. *S.3.2 score evaluation*: the metric concerning the annual carbon sequestration over the carbon storage is estimated as the ratio of *CSEQ* (quantified in the step 3) to *CS* (quantified in the step 2), expressed as an annual percentage. Subsequently, the S.3.2 score is estimated, according to Equation (61), as a ratio in which the numerator is the difference of the score of the aforementioned metric against the score of the baseline metric ($T_{baseline}$) of the carbon sequestration and the denominator is the score of the same baseline metric, multiplied by 100, so that S.3.2 score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.3.2 = \frac{\left[\left(\frac{CSEQ}{CS} \cdot 100\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \ \leq 100 \tag{61}$$

   If the metric score is greater than the baseline metric score, S.3.2 score results into is positive value; noting though that the S.3.2 maximum score cannot exceed 100. If the metric score is lower than the baseline metric score, leading the difference in the numerator to be negative, S.3.2 score assumes a negative value indicating that the indicator performance does not satisfy the reference baseline, thus S.3.2 score is set equal to zero (0).

The score of the baseline metric in Equation (61) can be set based on the rationale that a neighbourhood/urban scale project should at least meet the local or national minimum requirements for annual carbon sequestration. However, a baseline metric score equal to 15 % can be used, also considering that an overall good visible greenery in urban areas was estimated equal to 15 % (Tang et al., 2023).

The indicator score is used to assess the share of annual GHG emissions of a neighbourhood/urban project that can be sequestered by ecosystems on land. The indicator score provides insights to verify the need to increase the annual carbon sequestration using natural based solutions and evaluate the impact of changes in land use in terms of capacity of carbon sequestration.

3.6.4 Example (S.3)

The example of the S.3 KPI evaluation is carried out by considering a **building scale project**, which is a new naturally ventilated multifamily residential building with a useful internal floor area of 2700 m^2, located in Turin (Italy). Central space heating and domestic hot water (DHW) are served by a natural gas fired non-condensing boiler, whereas cooling is served by local air-to-air heat pumps. The metered annual energy consumption due to natural gas and electricity from the grid is estimated equal to 18351 m^3 and 53360 kWh_e, respectively.

The evaluation of the S.3 KPI to minimise the GHG emissions of the building depends on the scores of S.3.1 and S.3.2 indicators.

The **S.3.1 score** is evaluated according to the three-step framework, as reported in Section 3.6.2, to estimate the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Annual delivered energy (Q) sub-metric evaluation*: following the same analysis as in the example of the S.1.1 score evaluation (Section 3.4.5), the breakdown of the the delivered energy per energy carrier allocated for the corresponding building services is summarised in Table 18.

Table 18. Example (S.3): annual delivered energy sub-metric evaluation.

Energy carrier	Q per energy carrier (kWh/year)	Building service	GHG emissions factor ($kgCO_2eq/kWh$)
Natural gas	173427	Heating, DHW	0.202 (Lo Vullo et al., 2022)
Electricity	3202	Cooling	0.258 for 2022 (EEA, 2024c)
Electricity	50158	Other (e.g. lighting, cooking, white appliances, plug loads)	0.258 for 2022 (EEA, 2024c)

Source: JRC.

2. *Annual operational GHG emissions (Annual OGHG) metric evaluation*: based on the annual delivered energy per energy carrier, estimated in step 1, and the corresponding emissions factors for each energy carrier (Table 18), the *annual OGHG* metric related to heating, DHW, and cooling building services is estimated by using Equation (54), as follows (Equation (62)):

$$Annual\ OGHG = \frac{(173417 \cdot 0.202) + (3202 \cdot 0.258)}{2700} = 13.3 \left[\frac{kgCO_2eq}{m^2year}\right] \quad (62)$$

For sake of completeness, the *annual OGHG* metric related to all the other uses of the building, e.g. lighting, cooking, etc. (Table 18), is estimated again by using Equation (54), as follows (Equation (63)). Hence, the *annual OGHG* metric for all uses of the building scale project is equal to 18.1 $kgCO_2eq/m^2year$.

$$Annual\ OGHG = \frac{(50158 \cdot 0.258)}{2700} = 4.8 \left[\frac{kgCO_2eq}{m^2year}\right] \quad (63)$$

3. *S.3.1 score evaluation:* having estimated the *annual OGHG* metric, S.3.1 is evaluated in relation to the national, i.e. Italian, and EU context, by setting the scores of the baseline metric at Italian and EU level, as follows:

   a) **Italian context** – S.3.1 is evaluated in relation to the national building stock. Specifically, the building scale project is located in the climate zone E, corresponding to a HDD range equal to 2101–3000, as defined by the Italian decree on thermal energy systems (DPR, 1993). The mean value of the operational GHG emissions for buildings located in the Italian climate zone E is 44.7 $kgCO_2eq/m^2$.year (DPR, 1993), corresponding to the $T_{baseline}$ score at national level. Having estimated the score of the *annual OGHG* metric for heating, DHW, and cooling uses (evaluated in step 2), and the baseline metric score at national level, S.3.1 score is evaluated by using Equation (55), as follows (Equation (64)).

$$S.3.1 = \frac{(44.7 - 13.3)}{44.7} \cdot 100 = 70.2 \quad (64)$$

   The S.3.1 indicator results into a positive score, pointing out the percentage reduction of the annual operational GHG emissions compared to the average annual GHG emissions of the Italian building stock for climate zone E. If the additional uses of the building scale project, such as cooking, lighting, etc., are considered, the score of the *annual OGHG* metric for all uses is equal to 18.1 $kgCO_2eq/m^2year$ (evaluated in step 2) and the S.3.1 score is found to be equal to 59.5, according to Equation (65).

$$S.3.1 = \frac{(44.7 - 18.1)}{44.7} \cdot 100 = 59.5 \quad (65)$$

b) **EU context** - S.3.1 is evaluated in relation to the EU building stock. According to data in Table 14, the average value of the annual operational GHG emissions for multi-family buildings located in South Europe is 30 $kgCO_2eq/m^2$.year that is assumed as the $T_{baseline}$ score at EU level. Similarly to the Italian context, having estimated the score of the *annual OGHG* metric for heating, DHW and cooling uses (evaluated in step 2), and the baseline metric score at EU level, S.3.1 score is evaluated by using Equation (55), as follows (Equation (66)).

$$S.3.1 = \frac{(30 - 13.3)}{30} \cdot 100 = 55.6 \quad (66)$$

The S.3.1 indicator results into a positive score, indicating the reduction of the annual operational GHG emissions of the buidilng compared to an EU average for South Europe. Similarly, if the additional uses of the building scale project, such as cooking, lighting, etc., are considered, the *annual OGHG* metric results into a score equal to 18.1 $kgCO_2eq/m^2year$ (evaluated in step 2) and the S.3.1 score is found to be equal to 38.3, according to Equation (67).

$$S.3.1 = \frac{(30 - 18.1)}{30} \cdot 100 = 39.6 \quad (67)$$

The comparison of the S.3.1 scores in relation to the Italian and EU context points out that the building scale project analysed at Italian level exhibits a better performance related to the reduction of operational GHG emissions, mainly depending on the the higher baseline metric score of the national building stock than one of the EU building stock. Furthermore, the comparision of the S.3.1 score at EU level with the EU 2030 target of GHG emission reduction (i.e. 55 %) underlines that the building scale project is on track, if the annual operational GHG emissions related to heating, DHW, and cooling uses are considered, as the indicator score indicates a percentage reduction of the annual operational GHG emissions equal to 55.6. However, considering the total energy consumption and all services, the indicator score needs to be improved, as it indicates a percentage reduction equal to 39.6.

The performance of the building scale project can be further impoved by decarbonising the building through the replacement of the on-site combustion of natural gas with a central heat pump using electricity. A zero-emissions building shall not generate any on-site carbon emissions from fossil fuels, according to the EPBD recast (Directive, 2024). However, the emissions factors for the grid electricity within the budilng scale project analysed are below the EU-27 average. Yet, the GHG emissions will still be lower considering the lower electricity consumption due to a much better energy efficiency performance of a heat pump compared to the boiler currently considered in the project.

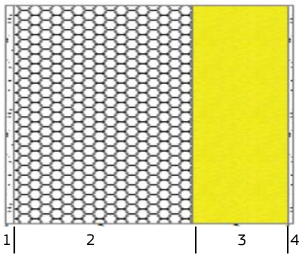
The **S.3.2 score** is evaluated according to the four-step framework, as reported in Section 3.6.3, to estimate the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Bill of Quantities (inventory) preparation:* relevant data is collected and reported for all building construction products/materials falling into the physical scope of the indicator. Specifically, the bill of quantities of all building elements/components classified by 'tier 1' in shell, core, and external works, as indicated in Table 15, needs to be prepared. Figure 28 provides an example of the bill of quantities of an external wall system of the building scale project, according to the classification in 'tier 1' shell, 'tier 2' façade, and 'tier 3' external wall (Table 15). The quantities to be reported in the BoQ are the masses (expressed in kg) of materials/construction products of the external wall needed over building lifetime.

Figure 28. Example (S.3): bill of quantities of the external wall system of the building scale project.

Tier 1: shell - Tier 2: façade - Tier 3: external wall system

External wall system layers



Layer		Density [kg/m^3]	Area [m^2]	Thickness [m]	Volume [m^3]	Mass [kg]	Assumed lifespan [years]	Normalised factor over building lifetime	Rounded up normalised factor over building lifetime	Mass needed over building lifetime [kg]
1	Plaster	1800	904	0.02	18.08	32544				65088
2	Brick	1800	904	0.3	271.2	488160				976320
3	Expanded polystyrene (EPS)	30	904	0.08	72.32	2169.6	30	1.6	2	4339.2
4	Plaster	1800	904	0.01	9.04	16272				32544

Source: JRC.

2. *GWP of construction products sub-metric evaluation:* The GWP-total values per functional unit of mass of construction product (expressed in kgCO_2eq/kg), are assigned to all the materials in the inventory defined in step 1 by using the available databases, i.e. an Environmental Product Declaration (EPD) for the thermal insulation material and the LCA database for all the other materials composing the external wall, as summarised in Table 19.

Table 19. Example (S.3): GWP-total per functional unit of the construction products of the external wall system of the building scale project.

Layer		Mass of material needed over building lifetime [kg]	GWP-total per functional unit [kgCO_2eq/kg]	Data source
1	Plaster	65088	0.26	LCA Database
2	Brick	976320	0.28	LCA Database
3	Expanded polystyrene (EPS)	4339.2	5.32	EPD
4	Plaster	32544	0.26	LCA Database

Source: JRC.

3. *Embodied GHG emissions (EGHG) metric evaluation*: based on the BoQ, reported in the step 1, and the GWP-total of each material per functional unit, collected in step 2, the GWP-total of each building construction materials composing the external wall is estimated according to the rationale in Figure 26. Subsequently, the sum of the GWP-total of each construction products provides the GWP-total of the external wall system, as summarised in Table 20.

Table 20. Example (S.3): GWP-total of the external wall system of the building scale project.

Layer		Mass of material needed over building lifetime [kg]	GWP-total per functional unit [kgCO_2eq/kg]	GWP-total of each material [kgCO_2eq]
1	Plaster	65088	0.26	16922.8
2	Brick	976320	0.28	273369.6
3	Expanded polystyrene (EPS)	4339.2	5.32	23084.5
4	Plaster	32544	0.26	8461.4
GWP-total of external wall system [kgCO_2eq]				321838.3

Source: JRC.

The procedure carried out for the external wall system needs to be applied to all the other building elements/components of the building scale project to carry out their GWP-total, grouped by tier 1 in shell, core, and external works, to subsequently summing up these results to obtain the GWP-total of the entire building, as summarised in Table 21.

Table 21. Example (S.3): GWP-total of the building scale project.

Tier 1	**GWP-total [kgCO$_2$eq]**
Shell	894735
Core	295195
External works	10670
GWP-total of building [kgCO$_2$eq]	**1200600**

Source: JRC.

Having estimated the GWP-total of the entire building equal to 1200600 kgCO$_2$eq, considering a reference study period of 50 years, the $EGHG_b$ metric is estimated by using Equation (57), as follows (Equation (68)):

$$EGHG_b = \frac{1200600\ kgCO_2eq}{2700\ m^2} = 445\ \frac{kgCO_2eq}{m^2} \tag{68}$$

4. *S.3.2 score evaluation:* having estimated the score of the $EGHG_b$ metric (evaluated in step 3), and assuming the score of the baseline metric equal to the mean of embodied GHG emissions per unit floor area for new residential buildings (i.e. $T_{baseline}$ = 600 kgCO$_2$eq/m^2), according to (Röck et al., 2022), S.3.2 is estimated by using Equation (58), as follows (Equation (69)).

$$S.3.2 = \frac{(600 - 445)}{600} \cdot 100 = 25.8 \tag{69}$$

The indicator results into a positive score equal to 25.8, thus indicating the percentage reduction of the embodied GHG emissions of the building scale project compared to the baseline metric score.

Having evaluated the scores of S.3.1 and S.3.2 indicators, **S.3 score** is evaluated by using Equation (52) and considering the indicator weights corresponding to the combination of the project classification according to scale, type, and main use into building, newbuild, and residential, respectively (Table 5). Hence, S.3 results into a score estimated equal to 43.1 or 37.1, depending on the Italian or EU context, that respectively corresponds to the *Good* or *Acceptable* performance class (Figure 21, newbuild/residential), as reported in Table 22.

Table 22. Example of S.3 evaluation (building scale) in relation to the national or EU context.

Italian context		
Indicator	**S.3.1**	**S.3.2**
Indicator score	70.2	25.8
S.3 score	0.4 • 70.2 + 0.6 • 25.8 = 43.1	
S.3 performance class	Good	
S.3 performance class score ($PCS_{S.3}$)	70	
EU context		
Indicator	**S.3.1**	**S.3.2**
Indicator score	55.6	25.8
S.3 score	0.4 • 55.6 + 0.6 • 25.8 = 37.1	
S.3 performance class	Acceptable	
S.3 performance class score ($PCS_{S.3}$)	45	

Source: JRC.

Although the S.3 KPI attains the *Good* performance class in relation to the Italian context, as its score is greater than 40, the KPI may also reach a performance class greater than *Acceptable* in relation to the EU context by introducing a few design improvements of the building to meet the more ambitious EU energy and GHG emission targets. Specifically, a first step to improve the KPI performance is to reduce the energy consumption during the use stage of the building to consequently lower the operational GHG emissions, thus improving the S.3.1 score. However, it is recognised that in the last decades the growing demand for the reduction of the operational energy of buildings to tackle the climate change may lead to an increase of embodied energy and GHG emissions (e.g. Chastas et al., 2016). Hence, especially in the case of new buildings that have to be compliant with NZEB requirements towards zero-emission requirements there is more emphasis on the embodied GHG emissions. This aspect is also reflected into the higher S.3.2 indicator weight for the KPI score evaluation. The second step to improve the KPI performance is thus to consider building construction materials with a lower carbon footprint, improving the S.3.2 score. Two scenarios of improvement are considered to obtain a more effective reduction of both operational and embodied GHG emissions.

The **first scenario of improvement** relies on the S.3.1 and S.3.2 score improvement. The S.3.1 improvement is achieved by reducing the energy consumption for space heating considering that the building scale project analysed exhibits a relatively high energy use intensity for space heating for a new building. Hence, the building envelope overall heat transfer coefficient is enhanced by using more thermal insulation and windows with a lower U-value to reduce the heat losses by 15 %. Accordingly, the delivered energy for natural gas drops from 173427 kWh_{th} (Table 18) to 147404 kWh_{th}, leading to a lower score of the annual operational GHG emissions metric related to heating, DHW, and cooling uses of the building, estimated by using again Equation (54), as follows (Equation (70)).

$$Annual\ OGHG = \frac{(147404\ \cdot\ 0.202) + (3202\ \cdot\ 0.258)}{2700} = 11.3\ \left[\frac{kgCO_2eq}{m^2year}\right] \quad (70)$$

Based on the new score of the *annual OGHG* metric, S.3.1 score can be re-estimated in relation to the baseline metric score at EU level by using again Equation (55), as follows (Equation (71)):

$$S.3.1 = \frac{(30 - 11.3)}{30} \cdot 100 = 62.3 \quad (71)$$

However, the use of additional insulation material will increase the embodied energy and carbon of the envelope construction by an average of 90.7 MJ/kg of thermal insulation material that varies depending on the type of thermal insulation material (Dascalaki et al., 2020). Usually this additional embodied energy and carbon can be recovered in about 2-3 years because of operational savings, depending on the prevailing weather conditions and heating loads. Selecting thermal insulation material with a lower carbon footprint may reduce the overall embodied GHG emissions to 669060 $kgCO_2eq$ or 247.8 $kgCO_2eq/m^2$. This is close to the average value of global trends for 'new advanced' buildings (i.e. passive houses, low-energy buildings or near/net zero energy or emission (NZEB) buildings) at 377 $kgCO_2eq/m^2$ (Röck et al., 2020). According to Röck et al. (2020), studies on 87 residential buildings exhibiting a 'new standard' energy performance class (i.e. buildings following standards regarding operational energy performance in place as legal requirements, thus considering buildings constructed after 2005) have reported a minimum embodied GHG emission value for a 50-year reference study period as low as 57 $kgCO_2eq/m^2$. Similarly studies on 43 residential buildings exhibiting a 'new adavanced' energy performance class (i.e. passive houses, low-energy buildings or near/net zero energy or emission (NZEB) buildings) also pointed out a minimum value of embodied GHG emissions equal to 73.5 $kgCO_2eq/m^2$. Similar targets are also set in the ASHRAE Standard 100 (ASHRAE, 2024).

Based on this, the S.3.2 improvement is obtained by considering the use of insulation material with lower embodied carbon, assuming a score of the EGHG metric equal to 247.8 $kgCO_2eq/m^2$. Based on the new score of the EGHG metric, S.3.2 score can be re-estimated in relation to the baseline metric equal to the EU mean of embodied GHG emissions per unit floor area for new residential buildings (i.e. $T_{baseline}$ = 600 $kgCO_2eq/m^2$, according to Rock et al., 2022) by using again Equation (58), as follows (Equation (72)).

$$S.3.2 = \frac{(600 - 247.8)}{600} \cdot 100 = 58.7 \quad (72)$$

Based on the new scores of S.3.1 and S.3.2 indicators within the first scenario of improvement, S.3 can be estimaded again at the EU context, resulting into a score equal to 59.5 that corresponds to the *Good* performance class (Figure 21, newbuild/residential), as reported in Table 23.

Table 23. Example of S.3 evaluation (building scale) according to the first scenario of improvement of S.3.1 and S.3.2 score.

EU context		
Indicator	**S.3.1**	**S.3.2**
Indicator score	62.3	58.7
S.3 score	0.4 • 62.3 + 0.6 • 58.7 = 60.1	
S.3 performance class	Good	
S.3 performance class score ($PCS_{S.3}$)	70	

Source: JRC.

The first scenario provides an effective improvement, as the KPI passed from the *Acceptable* to the *Good* performance class, also at EU level. However, building decarbonisation efforts and requirements mandate a shifting from onsite combustion and the use of natural gas to the electrification of all building services; hence, a second scenario of improvement is considered in this direction.

The **second scenario of improvement** also relies on the S.3.1 and S.3.2 improvement. The S.3.1 improvement is achieved by using a heat pump with a high seasonal performance of about 3.6, instead of the natural gas boiler, reducing the final energy use for space heating and DHW to about 36851 kWh_e. The score of the annual operational GHG emissions metric related to heating, DHW, and cooling uses of the building is then re-estimated by using Equation (54), as follows (Equation (73)).

$$Annual\ OGHG = \frac{(36851 + 3202) \cdot 0.258}{2700} = 3.8 \left[\frac{kgCO_2eq}{m^2year}\right] \quad (73)$$

Based on the new score of the *annual OGHG* metric due to the electrification of the building, S.3.1 score can be re-estimated in relation to the baseline metric score at both Italian and EU level by using again Equation (55), as follows (Equation (74) and (75) for the Italian and EU context, respectively).

$$S.3.1 = \frac{(44.7 - 3.8)}{44.7} \cdot 100 = 91.5 \quad (74)$$

$$S.3.1 = \frac{(30 - 3.8)}{30} \cdot 100 = 87.3 \quad (75)$$

The S.3.2 improvement is the same considered for the first scenario, thus S.3.2 score is equal to 58.7. Based on the new scores of S.3.1 and S.3.2 indicators, S.3 results into a score estimated equal to 71.9 or 70.3, depending on the Italian or EU context, that corresponds in both cases to the *Excellent* performance class (Figure 21, newbuild/residential), as reported in Table 24.

Table 24. Example of S.3 evaluation (building scale) according to the second scenario of improvement of S.3.1 and S.3.2 score.

Italian context		
Indicator	**S.3.1**	**S.3.2**
Indicator score	91.5	58.7
S.3 score	= 0.4 • 91.5 + 0.6 • 58.7 = 71.9	
S.3 performance class	Excellent	
S.3 performance class score ($PCS_{S.3}$)	100	
EU context		
Indicator	**S.3.1**	**S.3.2**
Indicator score	87.3	58.7
S.3 score	= 0.4 • 87.3 + 0.6 • 58.7 = 70.3	
S.3 performance class	Excellent	
S.3 performance class score ($PCS_{S.3}$)	100	

Source: JRC.

3.7 Enhance sustainable mobility in the built environment (S.4)

3.7.1 Description and assessment

At **building scale**, *enhance sustainable mobility in the built environment (S.4)* KPI is assessed through the following two indicators:

— *e-Mobility: electric vehicle (EV) parking (S.4.1).*

— *Alternative mobility: bicycle (S.4.2).*

The S.4 score, ranging from 0 to 100, at building scale is evaluated according to Equation (76) using different indicator weights ($w_{S.4.j}$) corresponding to the different combinations of the project classification according to type (i.e. newbuild or renovation)/main use (i.e. residential or non-residential) of a building scale project, as reported in Table 5. It is worth noting that the denominator of Equation (76) equals unity for each combination. As example, the indicator weights within Equation (76) refer to the combination of the project classification according to scale, type, and main use into building, newbuild, and residential, respectively.

$$S.4 = \sum_{j=1}^{2}\left(w_{S.4.j} \cdot S.4.j\right) \Big/ \sum_{j=1}^{2}\left(w_{S.4.j}\right) = 0.7 \cdot S.4.1 + 0.3 \cdot S.4.2 \qquad (76)$$

The S.4 KPI thresholds to associate the KPI score to the corresponding KPI performance class at building scale are illustrated in Figure 29.

Figure 29. S.4 performance classes and thresholds (building scale).

Performance class:	Low	Acceptable	Good	Excellent	
S.4 thresholds ($t_{S.4}$):	$0 \leq$	$t_{S.4,\ Acceptable}$	$t_{S.4,\ Good}$	$t_{S.4,\ Excellent}$	≤ 100
Newbuild - Residential		≥ 35	≥ 60	≥ 80	
Newbuild - Non-residential		≥ 40	≥ 60	≥ 80	
Renovation - Residential		≥ 30	≥ 55	≥ 75	
Renovation - Non-residential		≥ 35	≥ 55	≥ 75	

Source: JRC.

At **neighbourhood/urban scale**, *enhance sustainable mobility in the built environment (S.4)* KPI is assessed through the following five indicators:

— *e-Mobility: electric vehicle (EV) parking (S.4.1).*

— *Alternative mobility: bicycle (S.4.2).*

— *Public transportation systems – Extend (S.4.3).*

— *Public transportation systems – Usage (S.4.4).*

— *Public transportation systems – Accessibility (S.4.5).*

S.4 score is evaluated according to Equation (77) using the different indicator weights ($w_{S.4.j}$) corresponding to the different combinations of the project classification according to type (i.e. newbuild or renovation)/main use (i.e. residential or non-residential) of a neighbourhood/urban scale project, as reported in Table 5. It is worth noting that the denominator of Equation (77) equals unity for each combination. As example, the indicator weights within Equation (77) refer to the combination of the project classification according to scale, type, and main use into neighbourhood, renovation, and residential, respectively.

$$S.4 = \sum_{j=1}^{5} \left(w_{S.4.j} \cdot S.4.j\right) \Big/ \sum_{j=1}^{5} \left(w_{S.4.j}\right) = 0.25 \cdot S.4.1 + 0.15 \cdot S.4.2 + 0.15 \cdot S.4.3 + 0.25 \cdot S.4.4 + 0.2 \cdot S.4.5 \quad (77)$$

S.4 KPI thresholds to associate the KPI score to the corresponding KPI performance class at neighbourhood/urban scale are illustrated in Figure 30.

Figure 30. S.4 performance classes and thresholds (neighbourhood/urban scale).

Performance class:		Low	Acceptable	Good	Excellent	
S.3 thresholds ($t_{S.3}$):	$0 \leq$		$t_{S.3,\ Acceptable}$	$t_{S.3,\ Good}$	$t_{S.3,\ Excellent}$	≤ 100
Newbuild - Residential			≥ 20	≥ 70	≥ 80	
Newbuild - Non-residential			≥ 20	≥ 60	≥ 80	
Renovation - Residential			≥ 25	≥ 75	≥ 85	
Renovation - Non-residential			≥ 25	≥ 65	≥ 85	

Source: JRC.

3.7.2 e-Mobility: electric vehicles (EV) parking (S.4.1)

Electric vehicles are expected to play a crucial role in the decarbonisation and efficiency of the electricity system, through the provision of flexibility, balancing and storage services, especially through the development of smart charging and aggregation. The potential benefits of EVs to integrate with the electricity system and contribute to system efficiency and further absorption of renewable electricity can be exploited through the installation of a proper recharging infrastructure at building scale and the creation of public parking spaces with a recharging infrastructure at neighbourhood and urban scale.

At **building scale**, the *e-Mobility: electric vehicle (EV) parking (S.4.1)* indicator explores the EV-friendliness and availability of a parking facility in the form of car parking spaces serving a building to evaluate the proportion of car parking spaces with recharging points for EVs.

The S.4.1 score, which ranges between 0 and 100, is assessed according to a three-step framework that consecutively estimates the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Number of parking spaces (NPS) sub-metric evaluation*: the total number of car parking spaces serving a building are quantified. In line with the EPBD recast (Directive 2024), a parking space is included into the counting if it is (*i*) inside the building, and/or (*ii*) physically adjacent to the building (i.e. a car parking space within the property area or in the direct vicinity of the building), and/or (*iii*) having a clear link with the building (e.g. a car parking space, not adjacent to the building, but identified to exclusively serve the building and reacheable through a dedicated shuttle bus service).

2. *Number of recharging points (NRP) sub-metric evaluation:* the total number of car parking spaces with an EV-recharging point serving the building project needs to be quantified. Based on the NPS score, a parking space served by an EV-recharging point is included in the counting if the recharghing point has a power output higher than 3.7 kW (Regulation, 2023). Beyond this condition, recarching points where EVs typically

park for extended periods of time also need to be capable of smart recharching functionalities (Directive, 2024) to be included in the counting of NRP. Furthermore, each recharging point serves one electric vehicle at time.

3. *S.4.1 score evaluation*: the metric regarding the share of car parking spaces with a recharging point for EVs over the total number of car parking spaces is estimated as the ratio of NRP (quantified in step 2) to NPS (quantified in step 1), expressed as a percentage. Subsequently, the S.4.1 score is estimated according to Equation (78) as a ratio, in which the numerator is the difference of the score of the aforementioned metric against a baseline metric ($T_{baseline}$) score corresponding to the minimum required share of parking spaces equipped with a EV-recharging point, and the denominator is the same baseline metric score, multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.4.1 = \frac{\left[\left(\frac{NRP}{NPS} \cdot 100\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \leq 100 \qquad (78)$$

S.4.1 score indicates the extent to which the number of car parking spaces served by EV-recharching points over the total number of car parking spaces exceeds or subceeds the baseline metric score in relative terms. If the metric score is greater than the baseline metric score, S.4.1 score results into a positive value; noting though that the S.4.1 maximum score cannot exceed 100. If the metric score is lower than the baseline metric score leading the difference in the numerator to be negative, S.4.1 score results into a negative value pointing out that the indicator performance does not satisfy the baseline metric, thus the S.4.1 score is set equal to zero (0).

The score of the baseline metric ($T_{baseline}$) to be used in Equation (78) is defined by national or local ordinances, or it can be set based on the rationale that a project at building scale should at least meet the EU minimum requirements for car parking spaces with EV-recharching points, according to Article 14 'Infrastructure for sustainable mobility' of the recast EPBD (Directive, 2024), as summarised in Table 25.

Table 25. EU minimum requirements for baseline metric score corresponding to number of car parking spaces with an EV-recharging point in buildings, depending on building type/use and number of car parking spaces.

Building use	**Building type**	**No of car parking spaces (applicability threshold)**	**EU minimum requirement for baseline metric score**
Non-residential (excluding office buildings)	Newbuild/renovation[1]	> 5 parking spaces	At least 1 recharging point for every 5 parking space (20 %)
Non-residential (including only office buildings)	New/renovation[1]	> 5 parking spaces	At least 1 recharging point for every 2 parking space (50 %)
Non-residential buildings	Newbuild/renovation	> 20 parking spaces	At least 1 recharging point for every 10 parking space (10 %
Residential	Newbuild/ renovation[1]	> 3 parking spaces	At least 1 recharging point for every 3 parking space (33 %)

[1] According to the 2024 recast EPBD, in this case renovation is intended as major renovation.

Source: JRC; data from EPBD (Directive, 2024)

At **neighbourhood/urban scale**, the *e-Mobility: electric vehicle (EV) parking (S.4.1)* indicator addresses the availability of public car parking facilities within the project area by evaluating the proportion of car parking spaces served by a recharging point for EVs.

S.4.1 score, which ranges between 0 and 100, is assessed according to the following three-step framework that consecutively estimates the scores of sub-metrics and metrics to finally evaluate the indicator score:

1. *Number of recharging stations (NRS) sub-metric evaluation:* the total number of EV-recharging stations within the neighbourhood/urban area are quantified. A recharging station is included into the counting only if its recharging points have a power output greater than 3.7 kW (Regulation, 2023).

2. *Number of electric vehicles (NEV) sub-metric evaluation:* the total number of electric vehicles registered within the neighbourhood/urban area is quantified.

3. *S.4.1 score evaluation:* the metric concerning the number of EV-recharging stations per registered electric vehicle, is estimated as the ratio of NRS (quantified in the step 1) to NEV (quantified in the step 2), expressed as a percentage. Subsequently, the S.4.1 score is estimated, according to Equation (62), as a ratio in which the numerator is the difference of the score of the aforementioned metric against the score of the baseline metric ($T_{baseline}$) of the public car parking facilities equipped with a recharging station for EVs and the denominator is the score of the same baseline metric, multiplied by 100, so that S.4.1 score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.4.1 = \frac{\left[\left(\frac{NRS}{NEV} \cdot 100\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \leq 100 \tag{79}$$

   S.4.1 can also be assessed against a baseline that is set at a value representing the existing status at the beginning of the project. If the metric score is greater than the baseline metric score, S.4.1 results into is positive score; noting though that the S.4.1 maximum score cannot exceed 100. If the metric score is lower than the baseline metric score leading the difference in the numerator to be negative, S.4.1 score assumes a negative value indicating that the indicator performance does not satisfy the baseline metric, thus S.4.1 score is set equal to zero (0).

The score of the baseline metric in Equation (62) can be set based on the rationale that a neighbourhood/urban scale project should at least meet the local or national minimum requirements for EV-recharging stations to facilitate the alternative mobility and the use of EVs. The score of the baseline metric can be set based on mandatory minimum national requirements considering the total number of EVs in the area. For example, for publicly available electric recharging infrastructure for light duty road vehicles (i.e. cars and vans) there is a need for at least 1.3 kW for every battery electric vehicle and for every plug-in hybrid light-duty vehicle, a total power output of at least 0.8 kW must be provided through publicly accessible recharging stations (Regulation, 2023/1804). In addition, EU Member States shall ensure that a number of recharging stations are in place for heavy-duty vehicles in urban nodes and in safe and secure parklings. The number of electric light-duty vehicles per public EV charging point varies from about 2 vehicles per charging point in Korea to almost 100 in New Zealand, while the EU average public charging power capacity per light duty vehicle is 1.2 kW per EV (IEA, 2023).

3.7.3 Alternative mobility: bicycle (S.4.2)

The availability of bicycle parking spaces for new and majorly renovated buildings in the EU has been introduced as a design key-feature to remove barriers to cycling as a central element of a sustainable and zero-emission mobility (Directive, 2024). Bicycle parking spaces of a building project can be indoor or outdoor, depending on their location respectively inside the building or in an area belonging to the building, but placed outside it. Furthermore, the creation of connected networks of physically protected bicycle lanes at neighbourhood and urban scale, rather than individual or unprotected lanes, is generally regarded as the most important factor in promoting cycling.

At **building scale**, the *alternative mobility: bicycle (S.4.2)* indicator assesses the proportion of indoor and/or outdoor bicycle parking spaces of a building project in relation to building users (i.e. number of building occupants), as for non-residential buildings, or in relation to the number of dwellings, as for residential buildings.

The S.4.2 score, which ranges between 0 and 100, is assessed according to a three-step framework that consecutively estimates the scores of specific sub-metrics and metrics, which are evaluated differently based on the project classification according to use (i.e. residential or non-residential), to finally evaluate the indicator score, as follows:

1. *Number of bicycle parking spaces (NBPS) sub-metric evaluation*: the total number of available indoor and/or outdoor bicycle parking spaces of a building project needs to be quantified. This information can be verified from design documents in case of newbuild projects or from on-site inspection in case of renovation projects of existing buildings.
2. *User capacity (UC) of building* or *Number of dwellings (NDW) sub-metric evaluation*: the user capacity of building sub-metric is considered for non-residential building projects, whereas the number of dwelling

sub-metric is used for residential building projects, thus the evaluation of each sub-metric is carried out, as follows:

a) **Non-residential building**: the total user capacity of a non-residential building project, including both employees and visitors (if applicable), is quantified by retrieving relevant data from the building design documents, as for newbuild projects, or by using statistical data, as for renovation projects of existing buildings, if a registry is available

b) **Residential building**: the total number of dwellings is quantified by using the residential building design documents, as for newbuild projects, or a building survey, as for renovation projects of existing buildings.

3. *S.4.2 score evaluation:* the indicator score evaluation varies depening on the building project classification according to use, as follows:

a) **Non-residential building**: the metric regarding the number of bicycle parking spaces per user capacity of a building is estimated as the ratio of *NBPS* sub-metric (quantified in step 1) to *UC* sub-metric (quantified in step 2), expressed as a percentage. Subsequently, the S.4.2 score is evaluated according to Equation (80) as a ratio, in which the numerator is the difference of the aforementioned metric score against the score of a baseline metric ($T_{baseline}$) of bicycle parking spaces per user capacity and the denominator is the same baseline metric score, multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.4.2 = \frac{\left[\left(\frac{NBPS}{UC} \cdot 100\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \leq 100 \tag{80}$$

S.4.2 score indicates the extent to which the number of bicycle parking spaces per user capacity exceeds or subseeds the baseline metric score. If the metric score is greater than the baseline metric score, S.4.2 score results into a positive value; noting though that the indicator maximum score cannot exceed 100. If the metric score is lower than the score of the baseline metric leading to a negative difference in the numerator, S.4.2 results into a negative score indicating that the building performance does not satisfy the baseline metric, thus S.4.1 score is set equal to zero (0).

b) **Residential buildings**: the metric regarding the share of bicycle parking spaces over the number of dwellings is estimated as the ratio of *NBPS* sub-metric (quantified in step 1) to *NDW* sub-metric (quantified in step 2), expressed as a percentage. Subsequently, the S.4.2 score is estimated according to Equation (81) as a ratio, in which the numerator is the difference of the aforementioned metric score against the score of a baseline metric ($T_{baseline}$) corresponding to the minimum required share of bicycle parking spaces and the denominator is the score of the same baseline metric, multiplied by 100, so as the indicator score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.4.2 = \frac{\left[\left(\frac{NBPS}{NDW} \cdot 100\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \leq 100 \tag{81}$$

If the metric score is highierer than the baselinemetric score, S.4.2 score results into a positive value, noting though that the indicator maximum score cannot exceeds 100. If the metric score is lower than the baseline metric score leading the difference in the numerator to be a negative value, S.4.2 score points out that the indicator performance does not satisfy the baseline metric and S.4.2 score is set equal to zero (0).

The scores of the baseline metric to be used in Equation (80) and (81) are defined by national or local ordinances. Alternatively, the scores can be set based on the rationale that a project at building scale should at least meet the EU minimum requirements for bicycle parking spaces, according to Article 14 'Infrastructure for sustainable mobility' of the recast EPBD (Directive, 2024), as summarised in Table 26.

Table 26. EU minimum requirements for baseline metric score corresponding to bicycle parking spaces per user capacity or per dwelling in buildings, depending on building type/use and number of car parking spaces.

Building use	**Building type**	**No of car parking spaces (applicability threshold)**	**Minimum requirements for baseline metric score**
Residential	Newbuild	> 3 car parking spaces	2 bicycle parking spaces for every dwelling
	Renovation[1]		2 bicycle parking spaces for every dwelling If the above is not technologically and economically feasible, ensure as many bicycle parking spaces as appropriate
Non-residential	Newbuild/renovation[1]	> 5 car parking spaces	Bicycle parking spaces representing at least 15 % of the average or 10 % of user capacity of the building
Non-residential buildings	Newbuild/renovation	> 20 car parking spaces	Bicycle parking spaces representing at least 15% of the average or 10 % of user capacity of the building

[1] According to the 2024 EPBD recast, in this case renovation refer to as a major renovation.

Source: JRC; data from EPBD (Directive, 2024)

At **neighbourhood/urban scale**, the *alternative mobility: bicycle (S.4.2)* indicator evaluates the extension of the bicycle paths-lanes network in relation to the inhabitants of the designated project area and provides a useful measure of a diversified transportation system according to ISO 37120 (ISO, 2018).

The S.4.2 score, which ranges between 0 and 100, is assessed according to a three-step framework that consecutively estimates the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Length of bicycle paths and lanes (LBPL) sub-metric evaluation:* the total length (expressed in kilometres) of the available bicycle paths and lanes in a neighbourhood/urban scale project with a minimum width of a one-way bicycle lane equal to 1.5 m, although a width equal to 2 m is recommended to provide enough space for cyclists to ride side by side and pass each other safely (ISO, 2018). Indeed, the width of bicycle paths varies depending on the intended use and expected traffic volume, but it should be wide enough to accommodate two-way bicycle traffic, ranging from 2 to 3 m (ISO, 2018).

2. *Population (P) sub-metric evaluation:* the total number of inhabitants within the area of the neighbourhood or urban scale project is quantified, depending on the physical boundary of the project area.

3. *S.4.2 score evaluation:* the metric concerning the length of bicycle paths and lanes per 1000 inhabitants is estimated as the ratio of *LBPL* sub-metric (quantified in step 1) to one 1000th of *P* sub-metric (quantified in step 2), expressed as the kilometres of bicycle paths and lanes per 1000th inhabitants. Subsequntly, S.4.2 score is evaluated according to Equation (82) as a ratio, in which the numerator is the difference of the score of the aforementioned metric against the score of a baseline metric ($T_{baseline}$) of the bicycle paths and lanes length per 1000 inhabitants and the denominator is the score of the same baseline metric, multiplied by 100, so that the indicator score varies between 0 and 100.

$$S.4.2 = \frac{\left[\left(\frac{LBPL}{P} \cdot 1000\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \leq 100 \qquad (82)$$

   If the metric score is greater than the baseline metric score, S.4.2 score results into a positive value, noting though that the indicatormaximum score cannot exceed 100. If the metric score is lower than the score of the baseline metric leading to a negative difference in the numerator, S.4.2 score indicates that the indicator performance does not satisfy the baseline metric and S.4.2 score is set equal to zero (0).

The score of the baseline metric ($T_{baseline}$) in Equation (82) can be set based on the rationale that a neighbourhood/urban scale project should at least meet the local or national minimum requirements for bicycle paths and lanes length per 1000 inhabitants. However, an average value of 0.15 km/1000 inhabitants

(Eurostat, 2021) can be also assumed as the score of the baseline metric at EU level. Another option to set the baseline metric score takes into account the best practices of bicycle paths and lanes length per 1000 inhabitants in EU countries (Wolniak, 2023). Specifically, according to Wolniak (2023), a reference best practice is currently set at 7.8 km/1000 inhabitants in Finland, followed by Sweden (3.24 km/1000 inhabitants), Luxembourg (1.39 km/1000 inhabitants), Germany (1.59 km/1000 inhabitants) and Hungary (1.18 km/1000 inhabitants).

3.7.4 Public transportation systems: extend (S.4.3)

The *public transportation systems: extend (S.4.3)* indicator is considered exclusively at **neighbourhood/urban scale** to evaluate the extension of the public transportation network in relation to the population within the area of a neighbourhood or urban scale project, according to ISO 37120 (ISO, 2018). Cities with larger amounts of public transport might tend to be more geographically compact and supportive than areas relying on non-motorised modes of transportation. It is essential to evaluate the S.4.3 indicator along with the other two indicators relevant to the public transportation systems (i.e. S.4.4 and S.4.5, respectively concerning the usage and accessibility aspects) to identify an overall picture of the strengths and weaknesses of the public transportation systems within a neighbourhood/urban scale project.

The S.4.3 score, which ranges between 0 and 100, is assessed according to a three-step framework that estimates the scores of specific sub-metrics and metrics consecutively to finally evaluate the indicator score, as follows:

1. *Length of public transport systems (LPT) sub-metric evaluation:* the length of route (expressed in Km) covered by public transport systems operating within the area of the neighbourhood or urban scale project is estimated. Public transport shall include both high capacity systems (i.e. rail metro, subway systems, commuter rail) and low capacity systems (i.e. bus rapid transit systems, light rail, streetcars/tramways, buses, trolleybuses). Other passenger transport services may also be included. Data from each type of transport system can be included and listed individually to document the kilometres of public transport by system type. If different public transport systems cover a same route, the length shall be counted for each transport system (e.g if a bus and a streetcar cover the same 1-km route, the length of the public transport systems counts for 2 km). Relevant data should be gathered from municipal transport offices and local/regional transit authorities and can also be counted using computerised mapping, aerial photography or existing paper maps, all of which shall be field verified. This information may be gathered from transport system plans or other master plans.
2. *Population (P) sub-metric evaluation:* the total number of inhabitants within the area of the neighbourhood or urban scale project is quantified by using available statistical data.
3. *S.4.3 score evaluation:* the metric concerning the total length, in kilometres, of the public transport system within the neighbourhood/urban area per 10 000 inhabitants is assessed as the ratio of *LPT* sub-metric (quantified in step 1) to one 10000th of *P* sub-metric (quantified in step 2). Subsequently, the S.4.3 score is estimated according to Equation (83) as a ratio, in which the numerator is the difference of the score of the aforementioned metric against the score of a baseline metric ($T_{baseline}$) of the total length of public transport systems per 10 000 inhabitant and the denominator is the score of the same baseline metric, multiplied by 100, so that the indicator score varies between 0 and 100.

$$S.4.3 = \frac{\left[\left(\frac{LPT}{P} \cdot 10000\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \leq 100 \qquad (83)$$

   If the metric score is greater than the baseline metric score, S.4.3 score results into a positive value, noting though that the S.4.3 maximum score cannot exceed 100. If the metric score is lower than the baseline metric score, leading the difference in the numerator to be negative, S.4.3 score results into a negative value pointing out that the indicator performance does not satisfy the baseline metric and S.4.3 score is set equal to zero (0).

The score of the baseline metric ($T_{baseline}$) to be used in Equation (83) can be set based on the rationale that a neighbourhood/urban scale project should at least meet the minimum local or regional requirements for the total length of public transport systems (expressed in kilometers) per 10 000 inhabitants. The baseline metric score to evaluate the indicator may take its value at time zero, when the project objectives are established. Another option to set the score of the baseline metric refers to relevant standardised city data on the length of high and low capacity systems per inhabitants provided for 56 European cities by the Open Data Portal of the World Council on City Data (WCCD)[14], which is based on ISO 37120 (ISO, 2018), as reported for some representative European cities in Table 27.

Table 27. Baseline metric score corresponding to the total length of public transport systems (in km) per 10000 inhabitants of representative European cities.

City/Country	**City population (inhabitants)**	**City land area (km^2)**	**Length of public transport systems (in km) per 10000 inhabitants[1], as baseline metric score**		
			High capacity systems	**Low capacity systems**	**Total**
Amsterdam (The Netherlands)	834713	164.66	1.44	2.63	4.07
Barcelona (Spain)	1611822	102.16	1.59	5.82	7.41
Eindhoven (The Netherlands)	224788	88.84	0.09	5.21	5.3
Gdynia (Poland)	247478	135.00	0.44	9.78	10.22
Heerlen (The Netherlands)	87406	45.53	1.15	11.44	12.59
Kielce (Poland)	197704	110.00	1.16	67.09	68.25
Koprivnica (Croatia)	30872	90.94	0	2.59	2.59
London (UK)	8538700	1,572	1.43	4.51	5.94
Porto (Portugal)	214329	41.42	1.89	28.91	30.8
Rotterdam (The Netherlands)	618357	208.88	1.34	1.60	2.94
Sintra (Portugal)	382521	319.23	0.81	50.21	51.02
The Hague (The Netherlands)	519988	98.13	0.36	2.28	2.64
Valencia (Spain)	787266	137.48	1.44	5.87	7.31
Zagreb (Croatia)	790017	641.32	0.33	20.01	20.34
Zwolle (The Netherlands)	124896	119.3	4.65	0.15	4.8

[1] Data based on WCCD.

Source: adapted from Hajduk, 2022.

3.7.5 Public transportation systems: usage (S.4.4)

The *public transportation systems: usage (S.4.4)* indicator is considered exclusively for **neighbourhood/urban scale** projects to evaluate the usage of the public transportation network in relation to the population within the designated neighbourhood or urban area, according to ISO 37120 (ISO, 2018). Cities with higher transport ridership rates tend to invest more in their transport systems, also becoming more geographically compact. The transport usage does not focus exclusively on population's journeys to reach the work place, but it addresses the overall travel patterns in a city. This also provides insight into transportation policy, traffic congestion, accessibility and urban form. It is essential to evaluate the S.4.4 indicator along with the other two indicators relevant to the public transportation systems (i.e. S.4.3 and S.4.5 concerning the *extend* and *accessibility* aspects, respectively) to identify an overall picture of the strengths and weaknesses of the public transportation systems within a neighbourhood/urban scale project.

The S.4.4 score, which ranges between 0 and 100, is assessed according to a three-step framework that estimates the scores of specific sub-metrics and metrics consecutively to finally evaluate the indicator score, as follows:

1. *Number of public transport trips (NPTT) sub-metric evaluation:* the total annual number of public transport trips originating in area of the neighbourhood/urban scale project are determined. Public transport trips shall include trips via high capacity systems (i.e. heavy rail metro or subway, commuter rail) and low capacity systems (i.e. light rail, streetcars and tramways, bus, trolleybus) and other public transport services may also be included. Transport systems often serve entire metropolitan areas, and not just central cities. Public transport data should be gathered from a number of sources including municipal transport

[14] World Council on City Data (WCCD), https://www.dataforcities.org

authorities, official transport surveys, revenue collection systems (e.g. number of fares purchased) and national censuses.

The use of number of public transport trips with origins in the city itself will capture many trips whose destination is outside the city, but will generally capture the impact that the city has on the regional transport network. Trips made via "informal transport" services (e.g. minibuses not operated by the government or municipal transport corporation) shall not be counted because they are not part of the official transport network.

2. *Population (P) sub-metric evaluation:* the total number of inhabitants within a neighbourhood or urban area is quantified by using available statistical data.

3. *S.4.4 score evaluation:* based on the sub-metric scores above, the metric evaluating the annual number of public transport trips originating in area of the neighbourhood/urban scale project per capita, i.e. 'ridership of public transport', is estimated as the ratio of *NPTT* sub-metric (quantified in step 1) to *P* sub-metric (quantified in step 2). Subsequently, the S.4.4 score is estimated according to Equation (84) as a ratio, in which the numerator is the difference of the score of the aforementioned metric against the score of a baseline metric ($T_{baseline}$) of the public transport trips per capita and the denominator is the reference score of the same baseline metric, multiplied by 100, so that the indicator score varies between 0 and 100.

$$S.4.4 = \frac{\left[\left(\frac{NPTT}{P}\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \leq 100 \quad (84)$$

If the metric is greater than the score of the baseline metric, S.4.4 score results into a positive value, noting though that the S.4.3 maximum score cannot exceed 100. If the metric score is lower than the score of the baseline metric, leading the difference in the numerator to be negative, S.4.4 results into a negative score pointing out that the performance does not satisfy the baseline metric, thus S.4.4 score is set equal to zero (0).

The score of the baseline metric ($T_{baseline}$) to be used in Equation (84) can be set based on the rationale that a neighbourhood/urban scale project should at least meet the minimum requirements for the annual total public transport trips per capita. The baseline metric score to evaluate the indicator may take its value at time zero, when the performance objectives concerning the use of public transportation are established. Similarly to the S.4.3 indicator, another option to set the score of the baseline metric refers to relevant standardised city data on annual number of public transport trips per capita provided for 56 European cities by the Open Data Portal of the World Council on City Data (WCCD)[15], which is based on ISO 37120 (ISO, 2018), as reported for some representative European cities in Table 28.

Table 28. Baseline metric score corresponding to the total number of public transport trips per capita of representative European cities.

City/Country	City population	City land area (km^2)	Annual number of public transport trips per capita[1], as baseline metric score
Amsterdam (The Netherlands)	834 713	164.66	265
Barcelona (Spain)	1 611 822	102.16	442
Eindhoven (The Netherlands)	224 788	88.84	190
Gdynia (Poland)	247 478	135.00	240
Heerlen (The Netherlands)	87 406	45.53	65
Kielce (Poland)	197 704	110.00	177
London (UK)	8 538 700	1572	490
Porto (Portugal)	214 329	41.42	637
Rotterdam (The Netherlands)	618 357	208.88	248
Sintra (Portugal)	382 521	319.23	44

15 World Council on City Data (WCCD), https://www.dataforcities.org

The Hague (The Netherlands)	519 988	98.13	111
Valencia (Spain)	787 266	137.48	159
Zagreb (Croatia)	790 017	641.32	343
Zwolle (The Netherlands)	124 896	119.3	56

[1] Data based on WCCD.

Source: Hajduk, 2022.

3.7.6 Public transportation systems: accessibility (S.4.5)

The *public transportation systems: accessibility (S.4.5)* indicator is considered exclusively for **neighbourhood/urban scale** projects to evaluate the accessibility of the public transportation network in relation to the population within the area of the neighbourhood or urban scale project, according to ISO 37120 (ISO, 2018) and in line with the UN SDG indicator 11.2.1[16]. Proximity to reliable and connected public transport provides the essential basis to larger share the public transit mode thus reducing congestion and other externalities. Greater transportation options also improve the liveability of cities.This also provides insight into transportation policy, traffic congestion, accessibility and urban form.

The S.4.5 score, which ranges between 0 and 100, is assessed according to a three-step framework that estimates the scores of specific sub-metrics and metrics consecutively to finally evaluate the indicator score, as follows:

1. *Number of inhabitants (NI) sub-metric evaluation* the total number of inhabitants, within the area of the neighbourhood or urban scale project, that live within 0.5 km of public transit running at least every 20 minutes during peak periods is determined. Peak periods are intended as the two 3-hour periods in a day when the traffic volume is highest; usually occurring one in the morning and the other in the evening. Generally, peak periods differ by region and municipality. Comprehensive data on the location of public transport stops, a complete street network, and data on the spatial distribution of inhabitants within the area of the neighbourhood or urban scale project need to be collected. Data shall be in the form of geographic information system (GIS) layers, which are usually made available by local or regional authorities. Schedules of public transit stops are available from municipal public transportation operators. The georeferenced population census can be derived relating the inhabitants in the area with their address in the georeferenced municipal street guide. The result will be a point layer in which each point represents one inhabitant's place of residence. Once both transit stops and georeferenced population layers are included in the GIS, proximity buffers of the transit stops (500 m radius) shall be created with the help of the GIS buffer geoprocess.
2. *Population* (P) *sub-metric evaluation*: the total number of inhabitants within the neighbourhood or urban area is quantified by using available statistical data.
3. *S.4.5 score evaluation*: the metric concerning the share of inhabitants living within 0.5 km of public transit running at least every 20 minutes during peak periods over the total number of inhabitants within the neighbourhood or urban area is estimated as the ratio of *NI* sub-metric (quantified in step 1) to *P* sub-metric (quantified in step 2), expressed as percentage. Subsequently, S.4.5 score is assessed according to Equation (85) as a ratio, in which the numerator is the difference of the score of the aforementioned metric against the score of a baseline metric ($T_{baseline}$) of the total number of inhabitants living within 0.5 km of public transit running at least every 20 minutes during peak periods and the denominator is the score of the same the baseline metric, multiplied by 1000, so as the indicator score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.4.5 = \frac{\left[\left(\frac{NI}{P} \cdot 100\right) - T_{baseline}\right]}{T_{baseline}} \cdot 1000 \ \leq 100 \qquad (85)$$

If the metric score is greater than the baseline metric score, S.4.5 results into a positive score, noting though that the indicator maximum score cannot exceed 100. If the metric score is lower than the score

[16] UN SDG indicator 11.2.1: 'Proportion of population that has convenient access to public transport, by sex, age and people with disabilities', https://unstats.un.org/sdgs/metadata/files/Metadata-11-02-01.pdf

of the baseline metric, leading the difference in the numerator to be negative, S.4.5 results into a negative score demonstrating that the indicator performance does not satisfy the baseline metric, thus the indicator score is set equal to zero (0).

The score of the baseline metric ($T_{baseline}$) to be used in Equation (85) can be set based on the rationale that a neighbourhood/urban scale project should at least meet the minimum local or regional requirements for the inhabitants' accessibility to the public transportation network. The access to a public transport stop within a 500 meters walking distance, regardless of the foreseen frequency of the public transport service at that stop, is usually not a critical issue for most of the population in urban centres of European cities, according to a study by Poelman et al. (2020) measuring the proportion of population that has convenient access to public transport in line with the UN SDG indicator 11.2.1[17]. This study provides results for 685 urban centres in EU-27, EFTA countries and the United Kingdom, pointing out that, in more than 45 % of the cities reviewed, the share of population with access to a nearby stop exceeds 95 %. However, this figure could lower, since the frequency of the public transport service is taken into account; a recommended score for the baseline metric in Equation (85) is assumed equal to 90 %.

3.7.7 Example (S.4)

The example for the evaluation of the S.4 KPI is carried out by considering two separate projects referring to a building and an urban scale project, respectively.

The **building scale** project is a new naturally ventilated multifamily residential building with a useful internal floor area of 2700 m^2, located in Turin (Italy). The building features a total amount of 22 car parking spaces: all of them have pre-cabling to enable the installation of recharging points for EVs, while ten out of the 22 parking spaces have installed recharging points for EVs with a power output greater than 3.7 kW. The building is also served by 10 bicycle parking spaces.

The evaluation of the S.4 KPI at building scale to enhance the building characteristics related to sustainable mobility depends on the scores S.4.1 and S.4.2 indicators.

The **S.4.1 score** is evaluated according to the three-step framework, as reported in Section 3.7.2, leading to the estimation of the scores of the sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Number of parking spaces (NPS) sub-metric evaluation*: the total number of car parking spaces is equal to 22.
2. *Number of recharging points (NRP) sub-metric evaluation*: Out of the 22 car parking spaces, a total number of ten car parking spaces have recharging points for EVs with a power output higher than 3.7 kW.
3. *S.4.1 score evaluation*: the metric score estimated as the ratio of *NRP* (i.e. total number of car parking spaces with a recharging point, quantified in step 2) to *NPS* (i.e. total number of car parking spaces, quantified in step 1), is compared against the score of the baseline metric ($T_{baseline}$). Specifically, the $T_{baseline}$ score is estimated according to the EU minimum requirement of one recharging point for every three car parking spaces by using data in Table 25, as the building scale project is classified as newbuild/residential/with more than three parking spaces. Hence, the building scale project should have a minimum total number of recharging points (NRP_{min}) equal to around 7, as the new multi-family building accounts for 22 car parking spaces (i.e. 22/3 = 7.3), which translates to a baseline metric score of 31.8 %, according to Equation (86).

$$T_{baseline} = \frac{NRP_{min}}{NPS} \cdot 100 = \frac{7}{22} \cdot 100 = 31.8\ \% \tag{86}$$

Having evaluated the NPS and NRP sub-metric scores and the baseline metric score, the S.4.1 score is evaluated using Equation (78), as follows (Equation (87)).

[17] UN SDG indicator 11.2.1: 'Proportion of population that has convenient access to public transport, by sex, age and people with disabilities', https://unstats.un.org/sdgs/metadata/files/Metadata-11-02-01.pdf

$$S.4.1 = \frac{\left[\left(\frac{10}{22} \cdot 100\right) - 31.8\ \%\right]}{31.8\ \%} \cdot 100 = 42.9 \tag{87}$$

The indicator score is greater than the baseline metric score of 31.8 %, thus the S.4.1 score is positive and can be considered in the KPI score evaluation.

The **S.4.2 score** is evaluated according to the three-step framework, as reported in Section 3.7.3, leading to the estimation of the scores of specific sub-metrics and metrics related to **residential buildings**, to finally evaluate the indicator score, as follows:

1. *Number of bicycle parking spaces (NBPS) sub-metric evaluation*: the total number of bicycle parking spaces serving the building is assumed equal to 10.
2. *Number of dwellings (ND) sub-metric evaluation*: the residential building consists of a total number of 22 dwellings.
3. *S.4.2 score evaluation*: the metric score estimated as the ratio of NBPS (quantified in step 1) to ND (quantified in step 2) is compared against the score of the baseline metric. Specifically, the $T_{baseline}$ score is estimated according to the EU minimum requirement of 2 bicycle parking spaces for every dwelling by using data in Table 26, as the building scale project is classified as newbuild/residential and has more than three car parking spaces. Hence, the building scale project should have a minimum total number of bicycle parking spaces ($NBPS_{min}$) equal to 44, as the building project accounts for 22 dwellings, leading to a $T_{baseline}$ metric score equal to 200 %, according to Equation (88).

$$T_{baseline} = \frac{NBPS_{min}}{NDW} \cdot 100 = \frac{44}{22} \cdot 100 = 200\ \% \tag{88}$$

Having evaluated the *NBPS* and *NDW* sub-metric scores and the baseline metric score, S.4.2 score is evaluated using Equation (81), as follows (Equation (89)). As expected, the indicator score is negative, as the number of bicycle parking spaces per dwelling is lower than the baseline metric score. Hence, S.4.2 score is set equal to zero (0).

$$S.4.2 = \frac{\left[\left(\frac{10}{22} \cdot 100\right) - 200\ \%\right]}{200\ \%} \cdot 100 = -77.3\ \rightarrow S.4.2 = 0 \tag{89}$$

Having evaluated the scores of S.4.1 and S.4.2 indicators, **S.4 score** is evaluated by using Equation (76) and considering the indicator weights corresponding to the combination of the project classification as building scale, newbuild type, and residential main use (Table 5). Hence, S.4 results into a score estimated equal to 30 that corresponds to the *Low* performance class (Figure 29, newbuild/residential), as reported in Table 29.

Table 29. Example of S.3 evaluation (building scale).

Indicator	**S.4.1**	**S.4.2**
Indicator score	42.9	0
S.4 score	0.7 • 42.9 + 0.3 • 0 = 30	
S.4 performance class	Low	
S.4 performance class score ($PCS_{S.4}$)	25	

Source: JRC.

The S.4 KPI can attain a performance class higher than Low by increasing both the number of car parking spaces with EV-recharging point and bicycle parking spaces per dwelling. Considering a project **scenario of improvement** for which all 22 parking spaces in the building scale project have installed recharging points for EVs and three bicycle parking spaces for every dwelling are ensured leading to a total number of bicycle parking spaces equal to 66, then the scores of S.4.1 and S.4.2 indicators are re-estimated equal to 100 and 50, respectively, according to Equation (90) and (91). S.4.1 score indicates that the number of car parking spaces with EV-recharging point exceeds the baseline metric score leading to a S.4.1 score greater than 100. However, the indicator score is set equal to its maximum score that is 100.

$$S.4.1 = \frac{\left[\left(\frac{22}{22} \cdot 100\right) - \ 31.8\,\%\right]}{31.8\,\%} \cdot 100 = 214.4 \rightarrow S.4.1 = 100 \tag{90}$$

$$S.4.2 = \frac{\left[\left(\frac{66}{22} \cdot 100\right) - 200\,\%\right]}{200\,\%} = 50 \tag{91}$$

Based on the new scores of S.4.1 and S.4.2 indicators, S.4 results into a score estimated equal to 50 that corresponds to the *Excellent* performance class (Figure 29, newbuild/residential), as reported in Table 30.

Table 30. Example of S.4 evaluation (building scale) according to the scenario of improvement of S.4.1 and S.4.2 scores.

Indicator	**S.4.1**	**S.4.2**
Indicator score	100	50
S.4 score	0.7 • 100 + 0.3 • 50 = 85	
S.4 performance class	Excellent	
S.4 performance class score ($PCS_{S.4}$)	100	

Source: JRC.

The **neighbourhood/urban scale** project refers to the renovation of a whole urban area with a residential main use, located in Turin (Italy), including a total amount of 55 public electric car recharging stations equipped with recharging points with a power output greater than 3.7 kW. The number of electric cars registered in the designated urban area equals 1025, while the current local minimum requirements for public car parking facilities equipped with a recharging station is assumed equal to 3%. The urban area supports the alternative mobility providing bicycle paths and lanes for a total length of 121 km, according to the data provided by themunicipality. The total population of the city is estimated equal to 723540 inhabitants, according to the municipality records. Finally, the urban area is served by various high and low-capacity public transportation systems, which do not include a subway system, according to data provided by the municipality, as reported in Table 31. The same table also reports data on the total length of each public transportation system and the corresponding annual trips. The accessibility of the public transportation network is assessed using a geoportal platform. Currently, the local baseline metric score for the total length of public transport systems in the area is assumed equal to 5.3 km/10000 inhabitants, which compares well with other major European cities given in Table 27, and the local baseline metric score for the annual public transport trips in the area is assumed equal to 121 trips per capita.

Table 31. Example (S.4): public transportation systems within the area of the urban scale project.

Public transportation system	**Type of public transportation system**	**Total length (km)**	**Annual number of public transport trips originating in the area per transportation mode (million trips)**
High-capacity systems	Heavy rail metro	115	20
	Subway	0	0
	Commuter rail	29	12
Total (high-capacity systems)		**144**	**32**
Low-cpacity systems	Light rail	180	4
	Streetcars/Tramways	120	2
	Busses and trolleybuses	135	48
	Bus rapid transit	145	16
Total (low-capacity systems)		**580**	**70**
Total (high- and low-capacity systems)		**724**	**102**

Source: JRC.

The evaluation of the S.4 KPI at neighbourhood/urban scale depends on the scores of S.4.1, S.4.2, S.4.3, S.4.4 and S.4.5 indicators.

The **S.4.1 score** is evaluated according to the three-step framework reported in Section 3.7.2, leading to the estimation of the scores of the sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Number of recharging stations (NRS) sub-metric evaluation*: the total number of recharging stations for EVs in the designated urban area is equal to 55.
2. *Number of electric vehicles (NEV) sub-metric evaluation*: a total number of 1025 electric cars are registered in the designated urban area.
3. *S.4.1 score evaluation:* the metric score, estimated as the ratio of NRS (quantified in step 1) to NEV (quantified in step 2), leading to the share of recharching stations per EV, is compared against the score of the baseline metric ($T_{baseline}$) for the area that is currently assumed equal to 3 %. Considering the growth of electrification in transportation and the number of EVs in the city, there has been a strong effort to expand the public recharging stations. Having evaluated the NRS and NEV sub-metric scores and the baseline metric score, S.4.1 score is evaluated using Equation (79), as follows (Equation (92)).

$$S.4.1 = \frac{\left[\left(\frac{55}{1025} \cdot 100\right) - 3\,\%\right]}{3\,\%} \cdot 100 = 78.9 \tag{92}$$

   Doubling the number of public recharging stations is significant progress, but will need more stations throughout the area to continue serving the growing number of EVs.

The **S.4.2 score** is evaluated according to the three-step framework, as reported in Section 3.7.3, leading to the estimation of the scores of the sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Length of bicycle paths and lanes (LBPL) sub-metric evaluation*: the total length of the available bicycle paths and lanes in the urban area with a width not less than 1.5 m is reported at about 121 km.
2. *Population (P) sub-metric evaluation:* the total number of inhabitants within the urban area is estimated equal to 723540.
3. *S.4.2 score evaluation:* the metric score evaluated as the ratio of *LBPL* (quantified in step 1) per one 1000th of *P* (quantified in step 2), leading to the length of bicycle paths and lanes in km per 1000 inhabitants, is compared against the score of the baseline metric ($T_{baseline}$). Specifically, the $T_{baseline}$ score of the length of bicycle paths and lanes in km per 1000 inhabitants is assumed equal to the EU average of 0.15 km/1000 inhabitants (Eurostat, 2021).Having evaluated the LBPL and P sub-metric scores and the baseline metric score, S.4.2 score is evaluated using Equation (82), as follows (Equation (93)).

$$S.4.2 = \frac{\left(\frac{121}{723540} \cdot 1000\right) - 0.15}{0.15} \cdot 100 = 11.5 \tag{93}$$

The **S.4.3 score** is evaluated according to the three-step framework, as reported in Section 3.7.4, leading to the estimation of the scores of the sub-metrics and metrics to finally evaluate the indicator score, as follows

1. *Length of public transport systems (LPT) sub-metric evaluation:* the total length of routes covered by public transport systems, operating within the area of the urban scale project, is estimated equal to 724 km (Table 31).
2. Population *(P) sub-metric evaluation:* the total number of inhabitants within the area of the urban scale project is reported at 723540.
3. *S.4.3 score evaluation*: the metric score evaluated as the ratio of *LPT* (quantified in step 1) to one 10000th of *P* (quantified in step 2), leading to the length of public transport system in km per 10000 inhabitants, is compared against the score of the local baseline metric ($T_{baseline}$) for the area that is currently assumed

equal to 5.3 km/10000 inhabitants. Having evaluated the LPT and P sub-metric scores and using the local baseline metric score, S.4.3 score is evaluated using Equation (83), as follows (Equation (94)).

$$S.4.3 = \frac{\left[\left(\frac{724}{723540} \cdot 10000\right) - 5.3\right]}{5.3} \cdot 100 = 88.7 \quad (94)$$

The **S.4.4 score** is evaluated according to the three-step framework, as reported in Section 3.7.5, leading to the estimation of the scores of the sub-metrics and metrics to finally evaluate the indicator score, as follows:

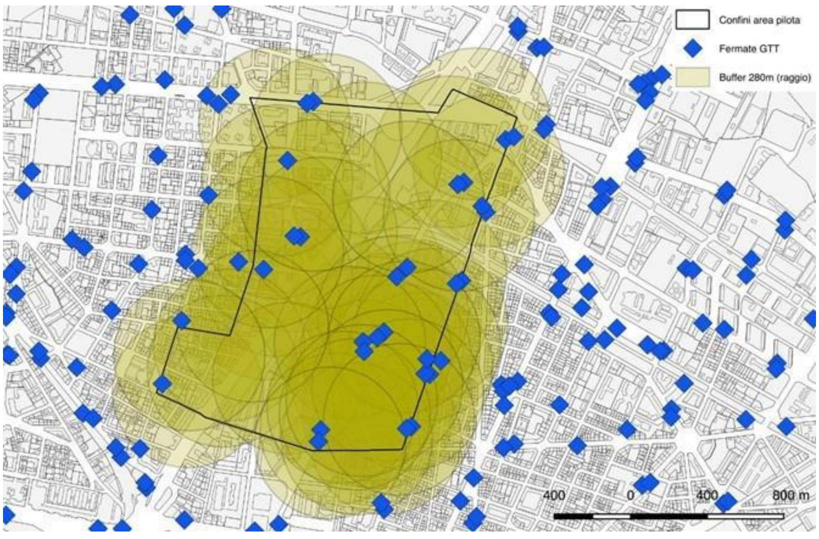
1. *Number of public transport trips (NPTT) sub-metric evaluation:* the annual total number of trips operating within the area of the urban scale project is 102 million (Table 31).
2. *Population sub-metric evaluation:* the total number of inhabitants in the area of the urban scale project is reported at 723540.
3. *S.4.4 score evaluation:* the metric score estimated as the ratio of NPTT (quantified in step 1) to P (quantified in step 2), leading to the number of public transport trips per capita, is compared against the score of the local baseline metric ($T_{baseline}$) for the area that is currently at 121 annual public transport trips per capita. Having evaluated the NPTT and P sub-metric scores and the baseline metric score, S.4.4 score is evaluated using Equation (84), as follows (Equation (95)).

$$S.4.4 = \frac{\left[\left(\frac{102000000}{723540}\right) - 121\right]}{121} \cdot 100 = 16.5 \quad (95)$$

The **S.4.5 score** is evaluated according to the three-step framework, as reported in Section 3.7.6, leading to the estimation of the scores of the sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Number of inhabitants (NI) sub-metric evaluation:* the total number of inhabitants within the area of the urban scale project that live within 0.5 km public transit running at least every 20 minutes during peak periods is determined using relevant data from the municipal public transportation operators and the addresses of the inhabitants within the project area. In this case, the municipality provided a GIS map (Figure 31) that incorporates data layers identifing the position of public transportation stops and the population distribution in the area, in shape format, through the Geoportale web platform.

Figure 31. The GIS map of the project area incorporating data layers of the position of public transportation stops and the population distribution.



Source: Geoportale web platform, adapted from CESBA MED (n.d.)

The accessibility to the public transportation network is estimated using the GIS map and the information described in step 1 of the indicator assessment framework. A buffer area is centered aroud each public transport stop using a 500 m radius, which is then combined with the data on the population served by the bus stop, avoiding double counting in case of buffer overlaps, as visualised in Figure 31. The public transportation stops are identified by the blue squares, all with public transit running at least every 20 min during peak periods. The proximity buffers of the transit stops are identified by yellow circles in Figure 31. Accordingly, the *NI* sub-metric was derived as 672 892 inhabitants that live within 0.5 km public transit running at least every 20 min during peak periods. Based on the *NI* evaluation, a small percentage of inhabitants living in the area outskirts of the urban scale project is excluded.

2. *Population sub-metric evaluation:* the total number of inhabitants in the area of the urban scale project is reported at 723540.

3. *S.4.5 score evaluation:* the metric score estimated as the ratio of *NI* (quantified in step 1) to *P* (quantified in step 2), leading to the number of inhabitants within the area of the urban scale project that live within 0.5 km public transit running at least every 20 min during peak periods, is compared against the score of the baseline metric ($T_{baseline}$). Having evaluated the *NI* and *P* sub-metric scores and setting the baseline metric score at the European value of 90 %, S.4.5 score is evaluated using Equation (85), as follows (Equation (95)).

$$S.4.5 = \frac{\left[\left(\frac{672892}{723540} \cdot 100\ \%\right) - 90\ \%\right]}{90\ \%} \cdot 1000 = 33.3 \qquad (96)$$

Having evaluated the scores of S.4.1, S.4.2, S.4.3, S.4.4, and S.4.5 indicators, the **S.4 score** is evaluated by using Equation (47), considering the indicator weights related to the combination of the project classification as urban scale, renovation type and residential main use (Table 5). S.4 results into a score equal to 46.4that corresponds to the *Acceptable* performance class (Figure 26, renovation/residential), as reported in Table 32.

Table 32. Example of S.4 evaluation (neighbourhood/urban scale).

Indicator	**S.4.1**	**S.4.2**	**S.4.3**	**S.4.4**	**S.4.5**
Indicator score	78.9	11.5	88.7	16.5	33.3
S.4 score	0.25 • 78.9 + 0.15 • 11.5 + 0.15 • 88.7 + 0.2 • 16.5 + 0.25 • 33.3 = 46.4				
S.4 performance class	Acceptable				
S.4 performance class score ($PCS_{S.4}$)	45				

Source: JRC.

The S.4 KPI can attain a performance class higher than Acceptable by considering the following **scenario of improvement**. The number of EV-recharging stations in the public parking facilities can be increased by 50 %, corresponding to a new total number of 83 EV-recharging stations, thus improving the S.4.1 indicator. The length of bicycle paths and lanes in the urban area with a width not less than 1.5 m can be expanded at 212 km, thus improving the S.4.2 indicator. In addition, efforts will focus on improving the public transport services, thus affecting S.4.4 and S.4.5 indicators. Accordingly, the *NPTT* sub-metric is improved by 35 % to reach a total of 137.7 million annual number of public transportation trips operating within the area of the urban scale project and the number of public transportation stops running at least every 20 min during peak periods will cover the entire population in the area of the urban project, thus the NI sub-metric will correspond to the entire population.

Based on this new scenario, the new score of S.4.1 indicator is estimated according to Equation (97), indicating that the new number of EV-recharging stations exceeds the baseline score, so the indicator score is set equal to 100 corresponding to the maximum score possible.

$$S.4.1 = \frac{\left[\left(\frac{83}{1025} \cdot 100\right) - 3\%\right]}{3\%} \cdot 100 = 169.9 \rightarrow S.4.1 = 100 \qquad (97)$$

The new score of S.4.2 indicator is estimated according to Equation (98), indicating that the expanded length of bicycle paths and lanes in the urban area leads to a new indicator score equal to 95.3.

$$S.4.2 = \frac{\left[\left(\frac{212}{723540} \cdot 1000\right) - 0.15\right]}{0.15} \cdot 100 = 95.3 \quad (98)$$

The new score of S.4.4 indicator is estimated according to Equation (99), indicating that the improved public transport services will increase the number of trips operating within the area of the urban scale project, so the new indicator score becomes 57.3.

$$S.4.4 = \frac{\left[\left(\frac{137700000}{723540}\right) - 121\right]}{121} \cdot 100 = 57.3 \quad (99)$$

The new score of S.4.5 indicator is estimated according to Equation (100), indicating that all the inhabitants within the area of the urban scale project will have access to public transit within 0.5 km running at least every 20 min during peak periods, so the indicator score results into a value equal to 111, thus it is set equal to 100 corresponding to the maximum score possible for the S.4.5 indicator.

$$S.4.5 = \frac{\left[\left(\frac{723540}{723540} \cdot 100\ \%\right) - 90\ \%\right]}{90\ \%} \cdot 1000 = 111 \rightarrow S.4.5 = 100 \quad (100)$$

Based on the new scores of S.4.1, S.4.2, S.4.4 and S.4.5 indicators, S.4 results into a new score estimated equal to 54.2 that corresponds to the *Excellent* performance class (Figure 30, renovation/residential), as reported in Table 33.

Table 33. Example of S.4 evaluation (neighbourhood/urban scale) according to the scenario of improvement of S.4.1, S.4.2, S.4.4, and S.4.5 scores.

Indicator	**S.4.1**	**S.4.2**	**S.4.3**	**S.4.4**	**S.4.5**
Indicator score	100	95.3	88.7	57.3	100
S.4 score	0.25 • 100 + 0.15 • 95.3 + 0.15 • 88.7 + 0.2 • 57.3 + 0.25 • 100 = 89.06				
S.4 performance class	Excellent				
S.4 performance class score ($PCS_{S.4}$)	100				

Source: JRC.

3.8 Minimise non-energy related environmental impacts to air and water (S.5)

3.8.1 Description and assessment

At **building scale**, *minimise non-energy related environmental impacts to air and water (S.5)* KPI is assessed through the following two indicators:

— *Indoor air quality (S.5.1).*

— *Water consumption (S.5.2).*

S.5 score is evaluated according to Equation (101) using the same indicator weights ($w_{S.5,j}$) for all the different combinations of the project classification according to type (i.e. newbuild/renovation)/main use (i.e. residential/non-residential) of a building scale project, as reported in Table 5.

$$S.5 = \sum_{j=1}^{2}\left(w_{S.5.j} \cdot S.5.j\right) \Bigg/ \sum_{j=1}^{2}\left(w_{S.5.j}\right) = 0.7 \cdot S.5.1 + 0.3 \cdot S.5.2 \quad (101)$$

S.5 KPI thresholds to associate the KPI score to the corresponding KPI performance class at building scale are illustrated in Figure 32.

Figure 32. S.5 performance classes and thresholds (building scale).

Performance class:	Low	Acceptable	Good	Excellent	
S.5 thresholds ($t_{S.5}$):	$0 \leq$	$t_{S.5,\ Acceptable}$	$t_{S.5,\ Good}$	$t_{S.5,\ Excellent}$	≤ 100
Newbuild - Residential		≥ 5	≥ 10	≥ 35	
Newbuild - Non-residential		≥ 5	≥ 15	≥ 35	
Renovation - Residential		≥ 5	≥ 10	≥ 35	
Renovation - Non-residential		≥ 5	≥ 15	≥ 35	

Source: JRC.

At **neighbourhood/urban scale**, *minimise non-energy related environmental impacts to air and water (S.5)* is assessed through one indicator, as follows:

— *Ground water recharge: permeability (S.5.2)*, through ground permeability.

The S.5.1 indicator, considered at building scale, is not applicable for neighbourhood/urban scale projects. Accordingly, S.5.1 is omitted in the evaluation of the S.5 score at neighbourhood/urban scale according to Equation (102) using the same indicator weights ($w_{S.5.j}$) for all the different combinations of the project classification according to type (i.e. newbuild or renovation)/main use (i.e. residential or non-residential) of a neighbourhood/urban scale project, as reported in Table 5.

$$S.5 = \sum_{j=1}^{2}\left(w_{S.1.j} \cdot S.1.j\right) / \sum_{j=1}^{2}\left(w_{S.1.j}\right) = 1 \cdot S.5.2 \quad (102)$$

The S.5 thresholds to associate the KPI score to the corresponding KPI performance class at neighbourhood/urban scale are illustrated in Figure 33.

Figure 33. S.5 performance classes and thresholds (neighbourhood/urban scale).

Performance class:	Low	Acceptable	Good	Excellent	
S.5 thresholds ($t_{S.5}$):	$0 \leq$	$t_{S.5,\ Acceptable}$	$t_{S.5,\ Good}$	$t_{S.5,\ Excellent}$	≤ 100
Newbuild - Residential		≥ 10	≥ 35	≥ 60	
Newbuild - Non-residential		≥ 5	≥ 30	≥ 40	
Renovation - Residential		≥ 5	≥ 25	≥ 50	
Renovation - Non-residential		≥ 5	≥ 20	≥ 30	

Source: JRC.

3.8.2 Indoor air quality (S.5.1)

The *indoor air quality (S.5.1)* indicator is considered exclusively at **building scale**. Indoor air pollution sources originate from human activities and indoor sources, such as cleaning or fuel combustion for cooking and heating, and even emissions from furniture and construction materials. Building ventilation can control and improve indoor air quality; however, the prevailing outdoor conditions have a direct impact on the building performance in relation to the energy use for mechanical ventilation and play a determinant role in naturally ventilated buildings.

The S.5.1 indicator is evaluated based on Level(s) indicator 4.1 'Indoor Air Quality' (Dodd et al., 2021d), in accordance with the European standard EN 16798-1 (CEN, 2019). The S.5.1 indicator considers air pollutants like volatile organic compounds (VOCs) emitted from materials, formaldehyde and carbon dioxide (CO_2). Possible sources of VOC emissions include building construction products and materials like ceiling tiles, paints and varnishes, textile floor and wall coverings, laminate and flexible floor coverings, wooden floor coverings, associated adhesives and sealants. The indicator assesses the concentration levels of air pollutants for a healthy indoor environment of a building scale project and provides an approach for ensuring suitable indoor air quality (IAQ) for occupants by recording the future sources of pollutants (e.g. intakes of outdoor air, etc.) or reducing the air pollutant concentration levels with different ventilation strategies. The S.5.1 indicator assesses the reduction of annual concentration of each one of the above mentioned air pollutants against a baseline concentration level, which is the limit value of each air pollutant, for the protection of human health.

S.5.1 score, which ranges between 0 and 100, is evaluated according to a four-step framework that consecutively estimates the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Identification of concentration limits of indoor CO_2:* in modern buildings, an increase in CO_2 above typical background air concentrations of 350-500 parts per million (ppm) in building spaces will be due to human respiration (Dodd et al., 2021d). Although a high CO_2 level itself can cause human sensory discomfort (e.g. at levels of several thousand ppm), it is unlikely that concentrations in indoor air would reach such high levels. Projected CO_2 levels can be used to design ventilation systems and in-situ monitoring of CO_2 in specific building zones can be used as a feedback signal to control ventilation rates for those same zones (e.g. in meeting rooms where CO_2 levels could vary significantly).

2. *Air pollutant concentration levels ($C_{pollutant}$) for building categories metric evaluation:* the air pollutant (e.g. VOC, formaldehyde, CO_2) concentrations, expressed as $\mu g/m^3$ or parts per billion (ppb) according to air pollutant, can be estimated for newbuild projects and/or measured in the indoor air for renovation projects of existing buildings, as follows:

   a) **Newbuild projects**, simulations can be used to predict VOC concentrations in buildings. Estimations can be performed with (*i*) non-physical empirical (statistical) models derived from measurement, such as Markov process models, and autoregressive moving average models, and/or (*ii*) physical models that are more accurate (Huang and Haghighat, 2003). However, physical models require data on material VOC emission properties which may not always be available. The United States Environmental Protection Agency (US EPA) - Air Quality Modeling[18], has made available user-friendly programs that can be used to perform indoor air quality modelling.

   b) **Renovation projects** of existing buildings, measurements can be performed using VOC analysers, according to ISO 16000-6 (ISO, 2021) following the general guidelines of sampling strategies of ISO 16000-1 (ISO, 2004). Measurement procedures for formaldeyde are performed according to the active sampling method of ISO 16000-3 (ISO, 2022) or the diffusing sampling method of ISO 16000-4 (ISO, 2011) that is suitable for measurements in atmospheres with conventional indoor air, relative humidity and for monitoring at air velocities as low as 0.02 m/s.

   The design concentration levels of air pollutants depend on the building type and the expectations level of indoor air quality in a building space. According to EN 16798-1 (CEN, 2019), there are four categories of expected indoor environmental quality (i.e. category-I, category-II, category-III, and category-IV), characterised by specific levels of air pollutant concentration. The IAQ categories indicted different comfort level. Category-I is the highest level of expectation, also recommended for spaces occupied by very sensitive and fragile persons with special requirements like some disabilities, sick, very young children and elderly persons, to increase accessibility. Category-II is the normal level of expectation, Category-III is the acceptable, moderate level of expectations, and Category-IV is the lowest level of expectation, acceptable only for a limited part of the year. Higher expectations are related to better control of IAQ and lower levels of concentration of air pollutants, but also generally to higher energy consumption. For existing buildings, in-situ periodic monitoring of particulate emissions during high occupancy periods can provide the necessary data for assessing the indoor conditions.

3. *Ventilation rate (q_{tot}) evaluation to reduce the air pollutant concentration levels:* two main approaches can be considered to estimate the design ventilation rates (i.e. design airflow rates), namely (*i*) pre-defined (default) ventilation air flow rates, and (*ii*) perceived air quality.

18 US EPA – Air quality modeling: https://www.epa.gov/air-research/air-quality-modeling

The *first approach* based on the default ventilation airflow rates for the four IAQ categories (I, II, III, and IV) is the simpliest method to estimate the minimum ventilation air flow rate, according to Level(s) indicator 4.1 'Indoor Air Quality' (Dodd et al., 2021d). The default ventilation rates for a room in an office building range from 5.5 (category-IV) to 20 (category-I) l/s/person and from 0.55 (category-IV) to 2 (category-I) l/s/m^2. When applied to a specific building zone (in terms of occupancy density), the default ventilation rates are estimated for a desirable category. The default predefined ventilation airflow rates, according to EN 16798-1 (CEN, 2019), can be expressed by a combination of one or more of the following components: total design ventilation for people and building components (q_{tot}); design ventilation per unit floor area (q/m^2), design ventilation per person (q_p); design air change rates per hour (ach); design opening areas (A_{tot}). Design ventilation air flow rates for ventilation systems in residential buildings consider the following coefficients to apply the components above (CEN, 2019): the supply air flow based on the ventilation per person ranges from 4 (category-III) to 10 (category-I) l/s/person, the supply air flow based on perceived IAQ for adapted persons (q_p) from 1.5 (category-III) to 3.5 (category-I) l/s/person or for building (q_B) from 0.1 (category-III) to 0.25 (category-I) l/(s.m^2), and the supply air flow based on total ventilation including air infiltration ranges from 0.35 (category-III) to 0.49 (category-I) l/(s.m^2) or from 0.5 to 0.7 ach. Category IV is intended for the evaluation of IAQ in existing residential buildings where the space for installations is limited and the total ventilation including air infiltration is 0.23 l/(s.m^2) or 0.4 ach.

Furthermore, it is worth noting that for non-residential buildings, during unoccupied periods when the ventilation system is shut off, the minimum amount of air to be delivered prior to occupancy is 0.5 ach of the zone to be ventilated. In case the ventilation rate is lower, the total air flow rate for diluting emissions from building is between 0.15 and 0.6 l/s.m^2 of floor area. For residential buildings, the total air flow rate for dealing with building materials emissions is between 0.1 and 0.15 l/s.m^2.

The *second approach* based on the perceived air quality, which is the odour level in a space perceived by the occupants, focuses on the capability of the ventilation system to remove/dilute emissions (*i*) from occupants (bio-effluents) and (*ii*) from building materials and furnishings. Thus, the ventilation is the sum of the abovementioned two components. Specifically, the total ventilation rate for the breathing zone (q_{tot}), expressed in litre per second (l/s) is assessed according to Equation (103), which combines the ventilation for the emissions from occupants and the ventilation for the emissions from building materials for the different IAQ categories. In Equation (103), data for the reference ventilation rates for persons (q_p),expressed in litre per second per person (l/s/person) and the reference ventilation rate for building materials (q_B), expressed in litre per second per square meter (l/s.m^2) can be retrieved from EN 16798-1 (CEN, 2019). Furthermore, the variable n is the design value for the number of the persons in the room, and A_u is the useful internal floor area, expressed in m^2.

$$q_{tot} = n \cdot q_p + A_u \cdot q_B \tag{103}$$

Specifically, the reference ventilation rates accounting for the removal/dilution of bio-effluents (q_p) can be based on either adapted or non-adapted occupants and vary depending on the different IAQ categories and expected percentages of occupant dissatisfaction. People adapt to the odour from bio-effluents, but very little to the emission from building materials. Hence, the design ventilation rates are based on non-adapted persons for diluting emissions (bio-effluents) from occupants ranging from 2.5 (category-IV) to 10 (category-I) l/s/person, with an expected percentage of dissatisfied people at 40 % (category-IV) to 15 % (category-I), according to EN 16798-1 (CEN, 2019). However, it may be a reasonable approach to design specific room types for adapted persons mainly in residential buildings with the design ventilation rates for for diluting emissions (bio-effluents) from occupants ranging from 1 (category-IV) to 3.5 (category-I). Thereference ventilation rates accounting for the removal/dilution of emissions from building (q_B) vary depending on the different IAQ categories and type of buildings, differentiated in very low, low, and non-low polluting building, according to EN 16798-1 (CEN, 2019). A low polluting building means that the majority of the materials are low polluting. Examples of low polluting materials are natural traditional materials (e.g. stone and glass), which are known to be safe with respect to air pollutant emissions. In addition, materials have emissions of total volatile organic compounds (TVOC) below 0.2 mg/m^{2}h, formaldehyde below 0.05 mg/m^{2}h, ammonia below 0.03 mg/m^{2}h, carcinogenic compounds (IARC) below 0.005 mg/m^{2}h and are not odorous (dissatisfaction with the odour is below 10 %). A building is very low polluting if all materials are very low polluting and indoor smoking has never been allowed. Very low polluting materials are natural traditional materials (e.g. stone, glass and metals). In addition, materials have emissions of TVOC below 0.1 mg/m^{2}h, formaldehyde below 0.02 mg/m^{2}h, ammonia below 0.01

mg/m²h, IARC below 0.002 mg/m²h, and dissatisfaction with the odour is below 10 %. The design ventilation rates for diluting emissions from different type of buildings range for very low polluting buildings from 0.15 (category-IV) to 0.5 (category-I) l/s m^2); for low polluting buildings from 0.3 (category-IV) to 1.0 (category-I) l/(s m^2); and for non low-polluting buildings from 0.6 (category-IV) to 2.0 (category-I) l/(s m^2). In all cases, the minimum total ventilation rate for health is 4 l/s/person (CEN, 2019).

4. *S.5.1 score evaluation:* The S.5.1 score is evaluated according to Equation (104) as a ratio, in which the numerator is the difference of the score of a baseline metric ($T_{baseline}$), corresponding to the maximum limit of concentration level of the examined air pollutant, e.g. VOC, formaldehyde, CO_2, against the $C_{pollutant}$ metric (i.e. estimated/measured concentration level of an air pollutant, e.g. VOC, formaldehyde, CO_2, as evaluated in step 2) and the denominator is the score of the same baseline metric. The ratio is multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.5.1 = \frac{T_{baseline} - C_{pollutant}}{T_{baseline}} \cdot 100 \quad (104)$$

If the $C_{pollutant}$ metric score is lower than the score of the baseline metric, S.5.1 results into a positive score, noting though that the indicator maximum score cannot exceed 100. If the $C_{pollutant}$ metric score exceeds the baseline metric score, leading the difference in the numerator to be negative, S.5.1 results into a negative score indicating that the performance achieved does not satisfy the baseline metric and the indicator score is set to zero (0). For new buildings, the indoor air quality should at least meet the minimum requirements. For existing buildings may consider using as a baseline the average reported emissions value and track the relatively lower emissions and improvements.

The score of the baseline metric in Equation (104) depends on the air pollutant considered and relevant data on the maximum concentration level of a specific air pollutant can be retrieved from the following available standards and/or resources: (*i*) Standard 62.1-2022 on ventilation and acceptable indoor air quality (ASHRAE, 2022), (*ii*) Occupational Safety and Health Administration (OSHA) data on carbon Dioxide Exposure Limits[19], and (iii) according to Well v2 building standard for A01 air quality, total volatile organic compounds (TVOC) should be less than 500 μg/m³ and formaldehyde level should be less than 50 μg/m³ (IWBI, 2020). A typical score for the baseline metric for an acceptable indoor air quality that is often used for CO_2 concentrations is 1000 ppm (Felgueiras et al., 2023), although several other indoor environmental factors (e.g. temperature, humidity, particulate matter concentrations) and other relevant factors (e.g. occupancy, activity, length of time a space has been occupied) influence the IAQ and ventilation system performance (Persily, 2022). A $C_{pollutant}$ metric score being far above the expected baseline metric score may indicate that the ventilation is not sufficient and result into a poor indoor air quality.

3.8.3 Water consumption (building scale) or ground water recharge: permeability (neighbourhood/urban scale) (S.5.2)

At **building scale**, the *water consumption (S.5.2)* indicator is evaluated based on Level(s) indicator 3.1 'Use stage water consumption' (Donatello et al., 2021a), which promotes efficient use of water resources and use of wastewater (grey water, rainwater). It is worth noting that the total water consumption of a building scale project for the evaluation of S.5.2 indicator includes the water consumed in sanitary fittings/devices and the water-using appliances, also considering greywater (i.e. wastewater from sinks, wash basins, showers, baths, washing machines and dishwashers, excluding wastewater from WCs and urinals) and rainwater (i.e. rainwater collected from roofs, and/or from other impermeable or pervious ground surfaces depending on the risk of contamination and the intended end use). The use of water efficient fixtures can reduce water consumption. The reuse of greywater and rainwater can provide additional savings, and it can be applied to all building types, regardless of climate and morphology. However, the reuse of greywater mandates several complex and costly systems which occupy building space to filter and pump the water and need separate collection and distribution networks and measuring devices.

The S.5.2 score, which ranges between 0 and 100, is assessed according to a three-step framework that consecutively estimates the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

[19] Occupational Safety and Health Administration (OSHA), Carbon dioxide: https://www.osha.gov/chemicaldata/183

1. *Water-using appliances, sanitary devices and fittings identification*: all the water-consuming appliances and sanitary devices used in a building scale project need to be identified along with details that influence the water consumption (e.g. toilet flush volumes, maximum flow rates for taps, size of irrigated areas, etc.). Furthermore, any architecturally significant building features that relate to water consumption (e.g. gardens, green roofs, green walls, etc.) shall also be accounted for.

2. *Data collection on water consumption*: relevant data to obtain the water consumption of a building scale project may be derived from different sources depending on renovation or newbuild projects, as follows:

   a) **Renovation projects**, water consumption is obtained from measured data including meter readings of potable water consumption (e.g. from the water utility) and, potentially, meter readings of supplied rainwater and/or greywater. Alternatively, relevant data include: (*i*) estimated building occupancy rate (average full time equivalent occupants in the building per day), (*ii*) estimated number of days that the building is occupied for normal use (e.g. offices week work schedule and national holidays, exclude residents' holiday days), and (*iii*) estimated number of visitors, if they are significant compared to the building permanent occupants (mostly for non-residential buildings). When assessing visitors, it should also be considered against full time equivalents (e.g. 4 visitors staying for 2 hours could be equivalent to 1 person working 8 hours).

   b) **Newbuild projects**, water consumption of a new building is estimated using default occupancy rates, e.g. Annex A8 of EN 16798-1 (CEN, 2019), ISO 52000-1 (ISO, 2017a) can be considered to retrieve default occupancy rates, and default values for water consumption rates for all sanitary fittings/devices and water-using appliances, as summarised in Table 34, also including usage factors that are expressed per occupant, per day, e.g. flushes per occupant per day.

Table 34. Water consumption rate and usage factor default data for water-using appliances and sanitary devices/fittings.

Building use factor	335	days/annum		
Sanitary devices	**Consumption rates**		**Usage factor (per occupant (o), per day)**	
Toilet (full flush)	7.5	L/full flush	1	flushes/o/day
Toilet (small flush)	4.5	L/small-flush	4	flushes/o/day
Bathroom tap	10	L/minute	75	seconds/o/day
Shower	12	L/minute	360	seconds/o/day
Bath-tub	185	L/bath	0.11	baths/o/day
Kitchen tap	12	L/minute	240	seconds/o/day
Sanitary devices sub-total				
Water using appliances	**Consumption rates**		**Usage factor**	
Dishwasher	11.5	L/cycle	0.4	cycles/o/day
Washing machine	43.5	L/cycle	0.3	cycles/o/day
Appliances sub-total				
Irrigation	108.7	L/d		

Source: Donatello et al., 2021a.

The demand for irrigation depends on the type of vegetation (e.g. trees, bushes, creeping plants, mixed plants, or lawn grass), the water demand category for the species planted, the microclimate and the vegetation density.

3. *Potable water consumption (PWC) metric evaluation*: the PWC metric for residential buildings is the daily potable water consumption in litres per occupant, simulated or measured depending on newbuild or renovation projects, expressed in litres/occupant/day (L/o/d), that is estimated as the result of the total daily water consumption from all sanitary devices and water-using appliances of a building project minus the non-potable (greywater and rainwater) water consumption, normalised by the number of occupants.

4. *S.5.2 score evaluation:* the S.2.1 score is estimated according to Equation (105) as a ratio, in which the numerator is the difference of the score of a baseline metric ($T_{baseline}$), corresponding to the average national (or regional) daily water consumption per occupant (expressed in L/o/d for residential buildings), against

the *PWC* metric (evaluated in step 3), and the denominator is the score of the same baseline metric, multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.5.2 = \frac{T_{baseline} - PWC}{T_{baseline}} \cdot 100 \qquad (105)$$

If the *PWC* metric score is lower than the score of $T_{baseline}$ metric, S.5.2 results into a positive score, noting though that the indicator maximum score cannot exceed 100. If the *PWC* metric score exceeds the baseline metric score, leading the difference in the numerator to be negative, S.5.2 results into a negative score indicating that the performance achieved does not satisfy the baseline metric and the indicator score is set to zero (0). The water consumption should at least meet the minimum requirements for new buildings that have installed new fittings that are water efficient. For existing buildings to be renovated it may consider using as a baseline metric the average water use and track the relatively lower water consumption and improvements.

The score of the baseline metric to be used in Equation (105) can be set for **residential builings** at national level by considering the national averages for annual households' water use from public supply (expressed in m^3/inhabitant), available from Eurostat (2023a). Similarly, the score of the baseline metric can be set at EU level, by considering the median value of the aforementioned national data, that is estimated equal to around 40-50 m^3 per inhabitant per year, equivalent to 109 to 137 litres per day per inhabitant. National data of each EU Member State directly expressed as average daily water consumption per occupant for residential buildings is also available for 2021 (EurEau, 2021).

Regarding **non-residential buildings**, there are significant variations of water consumption depending on the building use (e.g. office, school, hotel, etc.), occupancy, equipment, operations, and landscape area. Hence, the *PWC* and $T_{baseline}$ metrics that are specific to the building use may better reflect the different activities and water consumption benchmarks for non-residential buildings. As example, the *PWC* and $T_{baseline}$ metric scores can be expressed in measure units that are different from water consumption per occupant per day used for residential buildings, according to the following aspects: functional aspects (e.g. water consumption per guest-night in a hotel, per meal served in a restaurant), people (e.g. water use per employee in an office building or per student in a school) and physical characteristics of the facility (e.g. water use per unit floor area) that is the most widely reported metric (US EPA, 2024). Typical water use data to set the $T_{baseline}$ metric score may be difficult to find for non-residential buildings at local or national level. In the absence of local data, it is possible to use average values for the normalised water use intensity as water consumption per unit floor area per year for similar building uses: e.g. 590.0 litres per m^2 per year for an office (or 22788.2 litres per employee per year), 441.7 litres per m^2 per year for a school (or 42396.6 litres per student per year), 2119.6 litres per m^2 per year for a hotel (or 126811.3 litres per guest room per year) (US EPA, 2024). It is also possible to use water consumption records over a period of a few years, if available, to derive an average score of the baseline metric for a specific building. In all cases, it is essential to use the same measure units for the *PWC* and the $T_{baseline}$ metric scores in Equation (105) to calculate S.5.2 for a non-residential building project.

At **neighbourhood/urban scale**, the *ground water recharge: permeability (S.5.2)* indicator is considered as relevant issues relate to the capacity of the soil to transmit water. Soil sealing by covering of soil surfaces with materials, such as concrete and asphalt, for new buildings, roads, parking places, as well as other public and private spaces, reduces ground permeability and its capacity to transmit water to the soil. This limits the water recharging of aquifers and reduces effluents, while often increasing the risk of flooding and water scarcity, also contributing to global warming.

S.5.2 score, which ranges between 0 and 100, is evaluated according to a four-step framework that consecutively estimates the scores of specific sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Data collection:* data on (*i*) soil characteristics and (*ii*) surface of developed (i.e. occupied by constructions) and/or undeveloped areas (i.e. areas uncovered by structures but with different paving) need to be collected, as follows :
   a) Soil characteristics: each type of soil/ground cover land use is characterised by a weighting factor per unit surface (m^2) related to its potential for vegetation growth and nature implementation, e.g. sealed

surface = 0; semi-open surfaces = 0.2; surfaces with vegetation, connected to soil below = 1, according to the 'biotope area factor' of the city of Berlin reported by the Senate Department for Urban Mobility, Transport, Climate Action and the Environment[20].

b) Surface of developed ($S_{a,1}$) and undeveloped ($S_{a,2}$) areas within the designated urban area need to be estimated, thus including areas with a different paving or occupied by constructions (i.e. green areas, surfaces paved with asphalt, surfaces occupied by buildings, etc.).

2. *Degree of built area (DBA) sub-metric evaluation*: the total surface of a designated urban area (S_a), expessed in m^2, is estimated as the sum of the surface of the developed areas ($S_{a,1}$) (i.e. areas covered with structures) within the designated urban area and the surface of the undeveloped areas ($S_{a,2}$) (i.e. areas uncovered by structures) within the designated urban area. Based on this data, the degree of built area (DBA) is estimated as the ratio of the surface of the developed areas to the total surface of the designated urban area, according to Equation (106).

$$DBA = \frac{S_{a,1}}{S_a} \tag{106}$$

It is worth noting that the *DBA* sub-metric score is used to estimate the score of the baseline metric ($T_{baseline}$) the of the needed soil permeability of the designated urban area, within the step 4 of the framework for the evaluation of S.5.2 score.

3. *Real permeability of the soil ($S_{a,perm}$) sub-metric evaluation:* different surface types are characterised by a corresponding different real permeability of the soil depending on specific permeaibility weighting factors. Hence, the real permeability of the soil of the designated urban area ($S_{a,perm}$) sub-metric, expressed in m^2, is estimated as the sum of the products of the i-th different surface type within the designated urban area ($S_{a,i}$), expressed in m^2, by the corresponding permeability weighting factors (α_i) per unit surface, according to Equation (107). Specifically the permeability weighting factors for each different i-th surface type (α_i) are reported in Table 35.

$$S_{a,perm} = \sum_{i=1}^{n} (S_{a,i} \cdot \alpha_i) \tag{107}$$

Table 35. Different surface types and corresponding permeability weighting factor per unit surface.

Surface type ($S_{a,i}$)	**Weighting factor (α_i)**	**Description of surface type**
Sealed surfaces (impermeable surface)	0.0 per m^2	Surface is impermeable to air and water and has no plant growth (e.g. concrete, asphalt, slabs with a solid subbase).
Partially sealed surfaces (semi-impermeable surface)	0.1 per m^2	Surface is permeable to water and air; as a rule, no plant growth (e.g. clinker brick, mosaic paving, slabs with a sand or gravel subbase).
Semi-open surfaces	0.2 per m^2	Surface is permeable to water and air, water infiltration, but no plant growth (e.g. sand, gravel, clinker brick with high water infiltration).
Green surfaces	0.4 per m^2	Surface is permeable to water and air, water infiltration and plant growth (e.g. gravel with grass, wooden cobbles, grass paving blocks).
Surfaces with vegetation, connected to the soil below	1.0 per m^2	Vegetation connected to soil below, available for development of flora and fauna.

[20] Berlin 'biotope area factor', https://www.berlin.de/sen/uvk/en/nature-and-green/landscape-planning/baf-biotope-area-factor/calculating-the-baf/

Rainwater infiltration per m² of roof area	0.2 per m²	Rainwater infiltration for replenishment of groundwater; infiltration over surfaces with existing vegetation.
Water surface	0.5 per m²	Rainwater fed water surface.
Surfaces with vegetation, unconnected to the soil below, small substrate thickness	0.5 per m²	Surfaces with vegetation that have no connection to the ground and 20 to 40 cm of soil covering.
Surfaces with vegetation, unconnected to the soil below, medium substrate thickness	0.6 per m²	Surfaces with vegetation that have no connection to the ground and 41 to 80 cm of soil covering.
Surfaces with vegetation, unconnected to the soil below, large substrate thickness	0.7 per m²	Surfaces with vegetation that have no connection to the ground and 81 to 150 cm of soil covering.
Surfaces with vegetation, unconnected to the soil below, very large substrate thickness	0.9 per m²	Surfaces with vegetation that have no connection to the ground but more than 150 cm of soil covering.
Vertical greenery with connection to the ground	0.5 per m²	Direct connection of the vertical greenery with the soil, supply with nutrients and water directly over the roots in the soil.
Vertical greenery without connection to the ground	0.7 per m²	Vertical or horizontal vegetation on a wall without direct connection to the soil on the ground, permanent planters supplying the vegetation, with artificial irrigation.
Extensive roof greening	0.5 per m²	Nature-like design of the roof surfaces with a substrate thickness under 20 cm without artificial irrigation. Through systems for water retention the metric can be increased to 0.6 (only for extensive roof greening).
Semi-intensive roof greening	0.7 per m²	Mixture of extensive and intensive roof greening with a substrate thickness of 15 to 50 cm (depending on the chosen plant), usually in combination with artificial irrigation.
Intensive roof greening	0.8 per m²	Design of the roof similar to ground-based green areas with a substrate thickness more than 50 cm, usually in combination with artificial irrigation.

Source: Adaptaed from Senate Department for Urban Mobility, Transport, Climate Action and the Environment, Berlin 'biotope area factor': https://www.berlin.de/sen/uvk/en/nature-and-green/landscape-planning/baf-biotope-area-factor/calculating-the-baf/

4. *S.5.2 score evaluation*: the metric concerning the real permeability of soil of the designated urban area over the total surface of the deisgnated urban area is estimated as the ratio of $S_{a,perm}$ (quantified in step 3) to the total surface (S_a), expressed as a percentage. Subsequently, the S.5.2 score is assessed according to Equation (108), as a ratio in which the numerator is the difference of the aforementioned metric score against the score of a baseline metric ($T_{baseline}$) of the needed permeability of soil, and the denominator is the score of the same baseline metric, multiplied by 100, so that the indicator score varies between 0 and 100.

$$S.5.2 = \frac{\left[\left(\frac{S_{a,perm}}{S_a}\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \qquad (108)$$

If the metric score of the share of the real permeability soil over the total surface area is greater than the baseline metric score, S.5.2 results into a positive score, noting though that the indicator maximum score is 100. A higher score implies that the area is more permeable, and a lower score indicates that the area is less permeable. If the metric score of the share of the real permeability soil over the total surface area is lower than the score of the baseline metric, leading to a negative difference in the numerator, S.5.2 score points out that the indicator performance does not satisfy the baseline metric and the and the indicator score is set to zero (0). For newbuild project, the normalised permeability should at least meet the minimum requirements. For the assessment of renovation projects of existing projects it is possible to use as a baseline metric score the current status and track the relative improvements.

The score of the baseline metric ($T_{baseline}$) of the needed permeability in Equation (108) can be estimated according to the different types of land use, the existing degree of built area, and project type of development (alterations or extensions due to renovation projects, or newbuild projects), according to the areas of application of the Berlin 'biotope area factor' of the city of Berlin reported by the Senate Department for Urban Mobility, Transport, Climate Action and the Environment[21], as summarised in Table 36.

Table 36. Baseline metric score of the needed soil permeability according to land use, degree of build area and project development type.

Renovation project (existing buildings)			**Newbuild project**	
Degree of built area (DBA) sub-metric score	**Baseline metric score (ratio)**	**Baseline metric score (%)**	**Baseline metric score (ratio)**	**Baseline metric score (%)**
Residential units (Residential use only and mixed use with no commercial use of open space)				
up to 0.37	0.60	60	0.60	60
0.38 to 0.49	0.45	45		
over 0.50	0.30	30		
Commercial use (Commercial use only and mixed use with commercial use of open space)				
	0.30	30	0.30	30
Public facilities (for cultural or social purposes)				
up to 0.37	0.60	60	0.60	60
0.38 to 0.49	0.45	45		
over 0.50	0.30	30		
Schools (general-education schools, vocational centres, education complexes, outdoor sports facilities)				
	0.30	30	0.30	30
Nursery schools and day care centres				
up to 0.29	0.60	60	0.60	60
0.30 to 0.49	0.45	45		
over 0.50	0.30	30		
Technical infrastructure				
	0.30	30	0.30	30

Source: Data from Senate Department for Urban Mobility, Transport, Climate Action and the Environment, Areas of application – Berlin 'biotope area factor': https://www.berlin.de/sen/uvk/en/nature-and-green/landscape-planning/baf-biotope-area-factor/areas-of-application/
.

3.8.4 Example (S.5)

The example for the evaluation of the S.5 KPI is carried out by considering two projects referring to a building and an urban scale project, respectively.

The **building scale** project refers to a residential multifamily building, located in Greece, with a useful internal floor area of 2700 m^2 and an occupancy estimated equal to 88 people. The desirable indoor air quality corresponds to the category-III for a building with acceptable, moderate level of expectations of indoor air quality. A typical dwelling with representative sanitary devices and water-using appliances can be considered within the building to estimate the water consumption and consequently extrapolate for the entire building. Garden irrigation can also be accounted with a typical water use profile. Each typical dwelling is also equipped with a small rainwater collector of 20 m^2 surface area, which can cover the needs for irrigation purposes.

The evaluation of the S.5 KPI at building scale to minimise the building non-energy environmental impacts to indoor air and water by assessing the ventilation rates for acceptable indoor air quality (S.5.1) and the freshwater consumption (S.5.2).

The **S.5.1 score** is evaluated according to the three-step framework, as reported in Section 3.8.2, leading to the estimation of the scores of the sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Identification of concentration limits of indoor* CO_2: the concentration of CO_2 emissions are considered to characterise the indoor air quality of the spaces of the building scale project. The IAQ category and

[21] Areas of application – Berlin 'biotope area factor': https://www.berlin.de/sen/uvk/en/nature-and-green/landscape-planning/baf-biotope-area-factor/areas-of-application/

expectation levels for the building scale project refer to the category-III, for an acceptable, moderate level of expectation.

2. *Air pollutant concentration levels ($C_{pollutant}$) for building categories metric evaluation*: the CO_2 concentration was estimated equal to a mean value at 1800 ppm.

3. *Ventilation rate (q_{tot}) evaluation*: since the IAQ category and expectation levels for the residential building scale project refer to the category-III, for an acceptable, moderate level of expectation, the ventilation rate for occupancy per adapted person (q_p) is 1.5 l/s/person and the ventilation rate for emissions from building materials (q_B) is 0.8 l/s/m^2 for a non-low polluting building, according to predefined values in the standard EN 16798-1 (CEN, 2019). The total ventilation rate *(q_{tot})* for the breathing zone is based on the perceived air quality approach evaluated by using Equation (109) to combine the ventilation for emissions from occupants and the building materials in the space for a non-low polluting building, as follows (Equation (109)):

$$q_{tot} = \left(88\,people\ \cdot\ 1.5\ \frac{l}{s.person}\right) + \left(2700\,m^2\ \cdot\ 0.8\frac{l}{s.m^2}\right) = 2292\ \frac{l}{s} \tag{109}$$

4. *S.5.1 score evaluation:* having evaluated the CO_2 concentration metric equal to 1800 ppm (estimated in step 2) and considering the score of the baseline metric for the indoor CO_2 equal to 1000 ppm (Felgueiras et al., 2023), S.5.1 score is estimated using Equation (104), as follows (Equation (110)). The S.5.1 indicator results into a negative score since the indoor CO_2 concentration is greater that the score of the baseline metric, thus indicating that the performance achieved is not sufficient and the indicator score is set to zero (0).

$$S.5.1 = \frac{(1000 - 1800)}{1000} \cdot 100 = -80 \rightarrow \mathrm{S.5.1} = 0 \tag{110}$$

An effective action to improve the indoor air quality and decrease the indoor concentrations consists in increasing the ventilation rate. However, this will increase energy consumption for mechanical ventilation. Alternatively, the CO_2 concentration may be reduced to a mean value below 1000 ppm, to obtain a similar improvement due to the increase of the ventilation rate.

The **S.5.2 score** is evaluated according to the four-step framework, as reported in Section 3.8.3, leading to the estimation of the scores of the sub-metrics and metrics to finally evaluate the indicator score, as follows:

1. *Water-using appliances, sanitary devices and fittings identification:* a typical dwelling within the building project is considered to identify (*i*) the sanitary devices, i.e. one toilet (full and small flush), one bathroom tap, one shower, one bath-tub, one kitchen tap, and (*ii*) water-using appliances, i.e. one dishwasher, and one washing machine. The occupants use the building for 345 days per year (i.e. building use factor). Garden irrigation for a small, vegetated area of mixed planting with medium density, a medium water demand, with a medium microclimate, and a manual irrigation system is also considered. The typical dwelling is also equipped with a small rainwater collector of 20 m^2 surface area, which can cover the needs for irrigation purposes.

2. *Data collection on water consumption:* the water consumption of the building project is based on estimated data of consumption rates and usage factors for all the sanitary devices and water-using appiances, as reported in Figure 34, leading to a total daily water consumption per occupant equal to 199.5 l/o/d.

Figure 34. Example (S.5): water consumption data for sanitary devices and water-using appliances.

Building use factor	345	days/annum				
Sanitary fittings	Consumption rates		Usage factor		Daily consumption per occupant	
Toilet (full flush)	7.5	L/full flush	1	flushes/o/day	7.5	L/o/d
Toilet (small flush)	4.5	L/small-flush	4	flushes/o/day	18	L/o/d
Bathroom tap	10	L/minute	75	seconds/o/day	12.5	L/o/d
Shower	12	L/minute	360	seconds/o/day	72	L/o/d
Bath-tub	185	L/bath	0.11	baths/o/day	20.35	L/o/d
Kitchen tap	12	L/minute	240	seconds/o/day	48	L/o/d
Sanitary devices sub-total					178.35	L/o/d
Water using appliances	Consumption rates		Usage factor		Daily consumption per occupant	
Dishwasher	11.5	L/cycle	0.4	cycles/o/day	4.6	L/o/d
Washing machine	43.5	L/cycle	0.3	cycles/o/day	13.05	L/o/d
Appliances sub-total					17.65	L/o/d
Irrigation	14.0	L/d			3.490	L/o/d
				Total	199.49	L/o/d

		Total Water Consumption (L/o/d)	Of which potable (L/o/d)	Of which non-potable (L/o/d)
Sanitary fittings and devices (e.g. toilets, taps, baths and showers).	Toilets	25.50	25.50	0.00
	Bathroom taps	12.50	12.50	0.00
	Showers	72.00	72.00	0.00
	Bath-tub	20.35	20.35	0.00
	Kitchen taps	48.00	48.00	0.00
	Sub-Total	178.35	178.35	0.00
Water using appliances (e.g. dishwashers and washing machines)	Dishwashers	4.60	4.60	0.00
	Washing machines	13.05	13.05	0.00
	Sub-Total	17.65	17.65	0.00
Irrigation	Irrigation	3.49	0.00	3.49
	TOTAL (L/o/a)	199.49	196.00	3.49

Source: Adapted from Donatello et al., 2021a.

3. *Potable water consumption (PWC) metric evaluation:* the building total water consumption is estimated equal to 199.5 L/o/d (evaluated in step 2) of which 196.0 L/o/d is the potable water consumption, corresponding to the PWC metric score, while the remaining 3.5 L/o/d is the non-potable water consumption, which refers to the water used for irrigation purposes.
4. *S.5.2 score evaluation:* having estimated the PWC metric (evaluated in step 3), the S.5.2 indicator is evaluated in relation to the national, i.e. Greek, context by setting the score of the baseline metric at Greek level. Specifically, the score of the baseline metric corresponds to the average daily potable water consumption per inhabitant in Greece, which was estimated equal to 139 L/o/d in 2021 (EurEau, 2021). Accordingly, the S.5.2 score is estimated using Equation (105), as follows (Equation (111)). The indicator is negative, as the daily potable water consumption of the building scale project exceeds the average consumption of the residential buildings in Greece. Hence, the S.5.2 score is set equal to zero (0).

$$S.5.2 = \frac{(139 - 196)}{139} \cdot 100 = -41.0 \rightarrow S.4.2 = 0 \tag{111}$$

Having evaluated the scores of S.5.1 and S.5.2 indicators, **S.5 score** is estimated by using Equation (101) and considering the indicator weights corresponding to the project classification according to the combination of scale/type/use as building/newbuild/residential (Table 5). However, both indicators resulted into a score equal to zero (0), as they do not meet the minimum baseline metric score, thus S.5 score also equals 0 that corresponds to the *Low* performance class (Figure 32, newbuild/residential), as reported in Table 37.

Table 37. Example of S.5 evaluation (building scale).

Indicator	S.5.1	S.5.2
Indicator score	0	0
S.5 score	0.7 • 0 + 0.3 • 0 = 0	
S.5 performance class	Low	
S.5 performance class score ($PCS_{S.5}$)	25	

Source: JRC.

It is recommended that S.5 indicator attains at least the *Acceptable* performance class. In this context, a **scenario of improvement** relying on the enhancement of both S.5.1 and S.5.2 indicators is considered.

Regarding the S.5.1 indicator, a scenario for which the examined pollutant decreases to 850 ppm is envisaged, thus the S.5.1 score is re-estimated by using again Equation (110), as follows (Equation (112)):

$$S.5.1 = \frac{(1000 - 850)}{1000} \cdot 100 = 15 \tag{112}$$

The total ventilation rate can also be re-evaluated, considering a low polluting building with 0.4 l/s.m², as follows (Equation (113)), leading to a significantly reduced ventilation rate that will also allow for smaller size ventilation system, that ensures additional energy savings for ventilation.

$$q_{tot} = \left(88\,people\ \cdot\ 1.5\frac{l}{s.person}\right) + \left(2700\,m^2\ \cdot\ 0.4\ \frac{l}{s.m^2}\right) = 1212\ \frac{l}{s} \quad (113)$$

Regarding the S.5.2 indicator, the use of more water efficient fixtures that will reduce the total daily potable water consumption per occupant by 35 % is considered. This translates into a reduction of the daily potable water consumption per occupant to 127.4 L/o/d, that corresponds to the new score of the *PWC* metric. Accordingly, the S.5.2 score can be re-evaluted by using again Equation (105), as follows (Equation (114)), thus resulting into a new positive score.

$$S.5.2 = \frac{(139 - 127.4)}{139} \cdot 100 = 8.3 \quad (114)$$

Based on the new scores of S.5.1 and S.5.2 indicators, S.5 results is re-estimated using again Equation (101) and resulting into a score estimated equal to 23.3 that corresponds to the *Good* performance class (Figure 32, newbuild/residential), as reported in Table 38.

Table 38. Example of S.5 evaluation (building scale) following the improvement of indicator scores.

Indicator	**S.5.1**	**S.5.2**
Indicator score	15	8.3
S.5 score	0.7 • 15 + 0.3 • 8.3 = 23.3	
S.5 performance class	Good	
S.5 performance class score ($PCS_{S.5}$)	70	

Source: JRC.

At **neighbourhood/urban scale**, the project refers to an existing neighbourhood which needs to be renovated. A lot of land, that is representative for the entire neighbourhood area, is considered and it accounts for a total surface area of 500 m², out of which 200 m² correspond to the developed surface area, which is covered mainly with residential structures, while the undeveloped surface area, corresponding to the area not covered by buildings, is 300 m². Hence the project is classified according to scale, type and use as neighborhood, renovation, and residential.

The evaluation of S.5 at neighbourhood/urban scale to minimise the non-energy environmental impacts related to water resources depends exclusively on *ground water recharge: permeability* (S.5.2) indicator

The **S.5.2 score** is estimated according to the four-step framework, as reported in Section 3.8.3, leading to the estimation of the scores of the sub-metrics and metrics to finally evaluate the indicator score, as follows:.

1. *Data collection:* data on the surface of developed and/or undeveloped areas are collected, along with the different surface types. The entire area has a total surface area (S_a) of 500 m². The developed area ($S_{a,1}$) is equal to 200 m², whereas the uncovered area ($S_{a,2}$) equal to 300 m² consists of the following different surface types ($S_{a,i}$): (*i*) asphalt, with a surface area of 150 m², (*ii*) gravel with grass, accounting for a surface area equal to 100 m², and (*iii*) open green area with vegetation, accounting for a surface area equal to 50 m².
2. *Degree of built area (DBA) sub-metric evaluation*: having collected the data in step 1, the DBA (i.e. land-structure ratio) is estimated by using Equation (107), as follows (Equation (115)):

$$DBA = \frac{200\,m^2}{500\,m^2} = 0.4 \quad (115)$$

3. *Real permeability of the soil ($S_{a,perm}$) sub-metric evaluation*: according to data collected in step 1 on the different surface types of the uncovered area of the designated urban area, i.e. asphalt ($S_{a,asphalt}$ = 150 m^2), gravel with grass ($S_{a,gravel}$ = 100 m^2), and open areas with vegetation ($S_{a,vegetation}$ = 50 m^2), the corresponding permeability weighting factors per unit surface are identified by using data in Table 35. Specifically, the permeability weighting factors for sealed surfaces, green surfaces, and surfaces with vegetation connected to the soil were considered for the asphalt ($a_{asphalt}$ = 0), gravel with grass (a_{gravel} = 0.4), and areas with vegetation ($a_{vegetation}$ = 1), respectively. Based on the above, the real permeability of the soil of the designated urban area ($S_{a,perm}$) is estimated by using Equation (107), as follows (Equation (116)):

$$S_{a,perm} = (150 \cdot 0) + (100 \cdot 0.4) + (50 \cdot 1) = 90\ m^2 \quad (116)$$

4. *S.5.2 score evaluation*: the metric score estimated as the ratio of $S_{a,perm}$ (real permeability of the soil of the designated urban area, quantified in step 3) to $S_{a,}$ (i.e. the total surface of the designated urban area, collected in step 1) is compared against the score of the baseline metric ($T_{baseline}$). Specifically, the baseline metric score is set to 45 %, according to data in Table 36, considering the following combination of land use, degree of built area, and project development type, respectively: residential use, a degree of built area into the range 0.38-0.49 since the DBA of the designated urban area averages 0.4 (as estimated in step 2), and renovation project.

   Having evaluated the $S_{a,perm}$ sub-metric score, the $S_{a,}$, and the baseline metric score, S.5.2 is estimated using Equation (108), according to Equation (117). The indicator score is negative, as the permeability of soil of the designated urban area is lower than the baseline metric score, which means that the area does not allow for sufficient water permeability because of the soil coverage. Hence, S.5.2 is set equal to zero (0).

$$S.5.2 = \frac{\left[\left(\frac{90}{500} \cdot 100\right) - 45\ \%\right]}{45\ \%} \cdot 100 = -60 \rightarrow S.5.2 = 0 \quad (117)$$

Based on the indicator score, the **S.5 score** will be found to be equal to zero (0), as the KPI is assessed only through the S.5.2 indicator, corresponding to a *Low* performance class (Figure 33, renovation/residential).

The S.5.2 score can be improved by replacing the impermeable areas with vegetation. Specifically, the asphalt surface equal to 150 m^2 can be converted into green areas with vegetation, so the different surface types of the uncovered area of the designated urban area become the gravel with grass ($S_{a,gravel}$ =100 m^2), and open areas with vegetation ($S_{a,vegetation}$ = 200 m^2). Consequently, the $S_{a,perm}$ sub-metric can be re-estimated by using again Equation (107), as follows (Equation (118)):

$$S_{a,perm} = (100 \cdot 0.4) + (200 \cdot 1) = 240\ m^2 \quad (118)$$

Based on the new score of the $S_{a,perm}$ sub-metric, the S.5.2 indicator is estimated again, according to Equation (119), resulting into a positive score.

$$S.5.2 = \frac{\left[\left(\frac{240}{500} \cdot 100\right) - 45\ \%\right]}{45\ \%} \cdot 100 = 6.7 \quad (119)$$

Having evaluated the new score of S.5.2 indicator, the S.5 score is estimated by using Equation (102), considering the indicator weights corresponding to the combination of the project classification according to scale/type/use into neighbourhood/urban, renovation, and residential, respectively (Table 5). Hence, S.5 results into a score corresponding to the S.5.2 score, thus attaining the *Acceptable* performance class (Figure 33, renovation/residential), as reported in Table 39.

Table 39. Example of S.5 evaluation (neighbourhood/urban scale).

Indicator	S.5.2
Indicator score	6.7
S.5 score	1 • 6.7 = 6.7
S.5 performance class	Acceptable
S.5 performance class score ($PCS_{S.5}$)	45

Source: JRC.

3.9 Minimise non-energy related environmental impacts from the built environment (S.6)

3.9.1 Description and assessment

Minimise non-energy related environmental impacts from the built environment (S.6) KPI is assessed through one indicator, at both **building** and **neighbourhood/urban scale**, as follows:

— *Construction and demolition waste (CDW) (S.6.1).*

The S.6 score, ranging from 0 to 100, is calculated according to Equation (120), thus corresponding to S.6.1 score.

$$S.6 = (w_{S.6.1} \cdot S.6.1)/w_{S.6.1} = 1.0 \cdot S.6.1 \tag{120}$$

The S.6 thresholds adopted in the self-assessment method to associate the KPI score to the corresponding KPI performance class at building, and neighbourhood/urban scales are illustrated in Figure 35.

Figure 35. S.6 performance classes and thresholds.

Performance class:	0 ≤	Low	$t_{S.6, Acceptable}$	Acceptable	$t_{S.6, Good}$	Good	$t_{S.6, Excellent}$	Excellent	≤ 100
S.6 thresholds ($t_{S.6}$):									
Building/Neighbourhood/Urban - Newbuild			≥ 10		≥ 25		≥ 55		
Building/Neighbourhood/Urban - Renovation			≥ 5		≥ 15		≥ 45		

Source: JRC.

3.9.2 Construction and demolition waste (S.6.1)

At **building scale**, S.6.1 is assessed based on Level(s) indicator 2.2 'Construction and demolition waste and materials' (Donatello et al., 2021c). CDW originates at sites where construction, renovation or demolition of buildings and/or other construction works takes place, thus coming in many different forms and containing material from a wide range of sources, including building materials, furnishings, insulation, concrete, and asphalt. Specifically, construction waste contains a variety of materials, typically generated during the construction process. Renovation waste can contain both construction-related materials and demolition-related materials. The European List of Wastes (Commission Decision, 2014) provides a harmonised classification of the different types of waste. Specifically, chapter 17 of the European list of wastes allows the classification of construction and demolition waste by specific codes for individual materials that can be collected separately at a construction or demolition site. It includes waste streams (i.e. hazardous and non-hazardous; inert, organic, and inorganic) resulting from construction, renovation, and demolition activities. S.6.1 indicator estimates the share of waste potentially recovered from the waste generated at the end of life of a building and aims to promote the construction and demolition waste minimisation and an efficient waste management. A complete bill of quantities and bill of materials of the building scale project, as used during the construction phase of a building (relevant information are also available for the evalution of S.3.2 indicator in Section 3.6.3), is useful to collect relevant data for the indicator evaluation.

The S.6.1 score, ranging from 0 to 100, is evaluated according to a four-step framework estimating relevant sub-metrics and metrics to finally evaluate the indicator score, as follows:

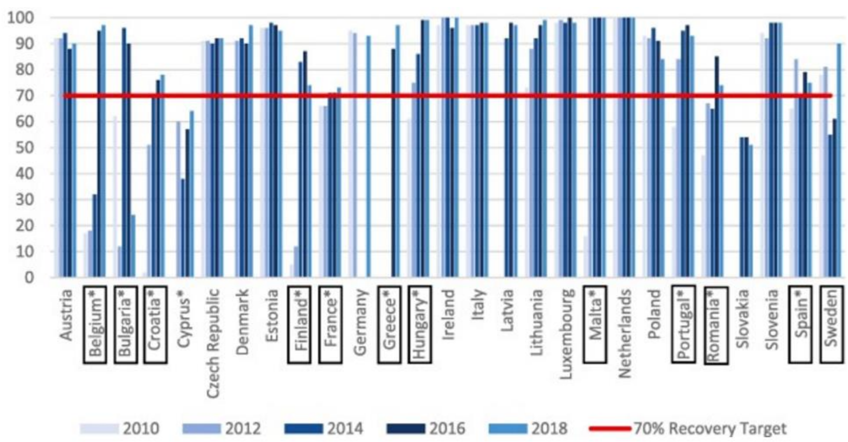
1. *Generated CDW (CDW_G) sub-metric evaluation:* the total quantity of CDW (expressed in kg) generated at the end of the life cycle (i.e. demolition stage) of a building scale project needs to be determined. In the case of a building scale renovation project, only the construction works related to the renovated part of a building are assessed. Construction plans can be used to extract data on dimensions and quantities of materials, components or elements that can be used without or after minor processing (i.e. reused materials) in a newbuild or renovation project at building scale, or quantities of materials that require significant processing (i.e. recycling materials) to be suitable for a newbuild or renovation project at building scale.
2. *Recovered CDW (CWD_R) sub-metric evaluation:* the various streams of CDW (expressed in kg) that could be recovered at the end of the life cycle (i.e. demolition stage) of a building scale project are quantified. This estimation shall be based on the design guidelines related to the Level(s) indicator 2.4 'Design for deconstruction' (Dodd et al., 2021e). Specifically, the indicator 2.4 in Level(s) includes estimates for each construction material or element, considering its type and the stream in which it can be classified (i.e. reuse, recycling). This quantity is disaggregated into the different types of CDW as per the chapter 17 entries of the European List of Waste (Commission Decision, 2014).
3. *S.6.1 score evaluation*: the metric regarding the share of CDW that can be recovered for reuse/recycling/recovery at the end of the life cycle of the building over the total CDW generated is estimated as the ratio of CDW_R (quantified in step 2) to CDW_G (quantified in Step 1), expressed as a percentage. Subsequently, the S.6.1 score is evaluated according to Equation (121) as a ratio, in which the numerator is the difference of the score of the aforementioned metric against the score of a baseline metric of recovery rates, and the denominator is the score of the same baseline metric, multiplied by 100, so that the indicator score can be expressed as a dimensionless value that varies between 0 and 100.

$$S.6.1 = \frac{\left[\left(\frac{CDW_R}{CDW_G} \cdot 100\right) - T_{baseline}\right]}{T_{baseline}} \cdot 100 \qquad (121)$$

   The higher the ratio of the recovered material, the less waste will be generated. If the metric score is greater than the score of the baseline metric, S.6.1 results into a positive score, noting though that the indicator maximum score cannot exceed 100. If the metric score is lower than the score of the baseline metric, leading the difference in the numerator to be negative, S.6.1 results into a negative score demonstrating that the indicator performance does not satisfy the baseline metric, thus the indicator score is set to zero (0).

The score of the *baseline metric* ($T_{baseline}$) to be used in Equation (121) can be set based on the rationale that the ratio of material that can be recovered from CDW should at least meet the EUminimum requirement setting a recovery rate of CDW of 70 % (by weight) for 2020, according to the Waste Framework Directive (Directive, 2008). However, the recovery rates vary significantly by Member State, therefore national data may be used to set the score of the baseline metric, mainly for projects in the EU countries which already exceed the 70 % EU recovery target. An overview of relevant national recovery rates of CDW in the EU-27 are reported in Figure 36 for the period 2010-2018 (Moschen-Schimek et al., 2023).

Figure 36. Recovery rates of CDW for EU-27 during the period 2010-2018.



Source: Moschen-Schimek et al., 2023.

At **neighbourhood and urban scale**, multiple building-scale assessments need to be performed by considering each building within the designated area and applying the same three-step framework defined for the evaluation of the S.6.1 score at single building scale. The evaluation of S.6.1 may also include other works for infrastructures within the designated area of the neighbourhood and urban scale project. Subsequently, the S.6.1 score at neighbourhood/urban scale is estimated as a weighted average of the S.6.1 indicator scores corresponding to the separate building scale assessments.

3.9.3 Example (S.6)

The example for the evaluation of the S.6 KPI only focuses on a building scale project.

The **building scale** project is a new single-family house, with a useful floor area of 100 m^2, which features four exterior 0.20 m-thick concrete walls. Each wall is 10 m long and 3 m high; three out of the four walls have two windows with the following dimensions each (1.4 m x 1.4 m), and a balcony door that is 1.4 m-long and 2.2 m-high. The fourth wall has two windows with the following dimensions each (1.4 m x 1.4 m) and a central entrance that is 1.0 m-long and 2.2 m-high featured with a timber door. Each wall is also insulated with extruded polystyrene (XPS) panels having a thichness of 0.05 m.

The evaluation of S.6 KPI at building scale to minimise the non-energy related environmental impacts of the building due to construction materials/components depends on the score of S.6.1 indicator.

The **S.6.1 score** is evaluated according to the three-step framework, as reported in Section 3.9.2, leading to the estimation of the sub-metric and metric scores to finally evaluate the indicator score, as follows:

1. *Generated CDW (CDW_G) sub-metric evaluation:* the bill of materials and quantities used for the building scale project are analysed to carry out the inventory of material masses (kg) or volumes (m^3), converted into the corresponding masses (kg) through the material density (kg/m^3), to evaluate the total CDW_G, as reported in Table 40. Specifically, the area of the exterior walls, excluding the openings and the entrance door, is equal to 92.88 m^2. The wall thickness is equal to 0.2 m, so it can be inferred that a volume of materials equal to approximately 18.58 m^3 has been used for the construction of the external walls. The load bearing structure of the walls corresponds to 20 % of this volume, which means approximately 3.72 m^3 of concrete has been used. Additionally, the XPS insulation panels used for the walls account for a total material volume equal to 4.64 m^3, considering that the insulation panels are 0.05 m thick. Finally, the entrancetimber door of the single-family house, accounts for a mass equal to around 80 kg Assuming that these building materials, i.e. concrete, XPS, and timber are the only ones being used for the building scale project, the sum of the three masses results into a total of 9135.5 kg, which corresponds to the score of the potential total CDW generated at the end of the building lifecycle.

Table 40. Inventory of materials for the evaluation of CDW_G.

Building component		Material	Material volume (m^3)	Material density (kg/m^3)	Mass (kg)
Wall	Total wall area[1] = 92.88 m^2 Thickness = 0.2 m Volume = 18.58 m^3	Concrete	0.2 · 18.58 = 3.72	2400	8916.5
Wall insulation	XPS panel thickness = 0.05 m	XPS	92.88 · 0.05 = 4.64	40	139
Entrance door		Timber			80
Potential total CDW_G					9135.5

[1] The calculation of the total area of walls excludes the area of windows and entrance door.

Source: JRC.

2. *Recovered CDW (CWD_R) sub-metric evaluation*: Based on the bill of materials and quantities for concrete, XPS, and timber carried out in step 1 (Table 40), it is assumed that 79 % of concrete can be recovered and 95 % of the XPS insulation will be recycled. Hence, a mass of 7044.1 kg of recovered concrete and 132.1 kg of recycled XPS insulation is obtained. Additionally, the total mass of timber used for the entrance door will be reused. The total mass of the recovered CDW at the end of the building lifecycle is obtained by summing the three partial masses of recovered concrete, recycled XPS insulation, and reused timber, resulting into a CWD_R score that equals to 7256.1 kg (i.e. CWD_R = 7044.1 kg + 132.1 kg + 80 kg = 7256.1 kg).

3. *S.6.1 score evaluation:* the metric score, estimated as the ratio of CWD_R (quantified in step 2) to CWD_G (quantified in step 1), is compared against the score of a baseline metric ($T_{baseline}$). Specifically, the $T_{baseline}$ score corresponds to the EU minimum requirement of the recovery rate of CDW equal to 70 %. Having evaluated the CWD_R and CWD_G sub-metric scores and the baseline metric score, S.6.1 score is estimated using Equation (121), as follows (Equation (122)).

$$S.6.1 = \frac{\left(\frac{7256.1}{9135.5} \cdot 100\right) - 70\ \%}{70\ \%} \cdot 100 = 13.5 \qquad (122)$$

Having evaluated the S.6.1 score, S.6 score is calculated by using Equation (120), thus resulting into a score estimated equal to 13.5 that corresponds to the *Acceptable* performance class (Figure 35, newbuild/residential), as reported in Table 41.

Table 41. Example of S.6 evaluation (building scale).

Indicator	**S.6.1**
Indicator score	13.5
S.6 score	= 1.0 · 13.5 = 13.5
S.6 performance class	Acceptable
S.6 performance class score ($PCS_{S.6}$)	45

Source: JRC.

3.10 Achieve the best possible greening of the public sector in terms of its economic involvement in the sustainability of the built environment (S.7)

3.10.1 Description and assessment

Achieve the best possible greening of the public sector in terms of its economic involvement (S.7) KPI is assessed through the following three indicators:

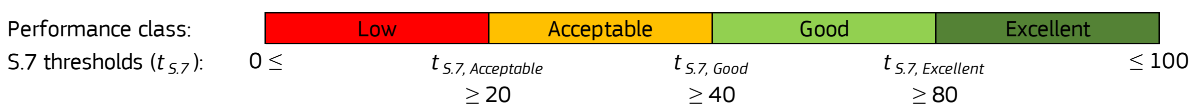
- *Social return of investment (SROI) (S.7.1).*
- *Degree of interdisciplinary integration (S.7.2).*
- *Gross value added to local economy from new business creation (S.7.3).*

S.7 score, resulting into the range 0-100, is evaluated according to Equation (123).

$$S.7 = \sum_{j=1}^{3}\left(w_{S.7.j} \cdot S.7.j\right) \Big/ \sum_{j=1}^{3}\left(w_{S.7.j}\right) = 0.2 \cdot S.7.1 + 0.3 \cdot S.7.2 + 0.5 \cdot S.7.3 \qquad (123)$$

The S.7 thresholds adopted in the self-assessment method to associate the KPI score to the corresponding KPI performance class are provided in Figure 37. The *Low*, *Acceptable*, *Good*, and *Excellent* performance classes for the S.7 KPI correspond to the following ranges of S.7 scores, i.e. 0 ≤ S.7 < 20, 20 ≤ S.7 < 40, 40 ≤ S.7 < 80, and 80 ≤ S.7 ≤ 100, respectively.

Figure 37. S.7 performance classes and thresholds.



Source: JRC.

S.7 and its three associated indicators can be applied at all the three spatial scales of a project (i.e. building, neighbourhood and urban), including both newbuild and renovation projects with residential and non-residential main use.

3.10.2 Social return on investment (S.7.1)

The *social return on investment (SROI) (S.7.1)* indicator refers to the SROI framework to measure and account for the value created by a project beyond its financial costs and benefits, over the initial public investment of the project. It considers the social, environmental, and economic value and benefits of a project and assesses them in monetary terms, based on local stakeholders' perspective. SROI is grounded in the 'theory of change', which is a logic model of the relationship among inputs, outputs, outcomes, and impacts of a project (Ruff, 2020). Specifically, in the SROI analysis, inputs are the resources involved in the creation, development and delivery of a project; outputs refer to a summary of the activities involved in the overall project; outcomes correspond to the changes that occur as a result of a project 'outputs'; and impacts represent the effective outcomes attributed directly to a project, thus eliminating (*i*) deadweights (i.e. the outcomes occurring regardless of the delivery of a project) and displacement (i.e. if applicable, the assessment of how much of the outcome has displaced other outcomes), (*ii*) attribution, i.e. the outcomes being a result of external factors, and (*iii*) drop-off (Nicholls et al., 2012). The SROI methodology consists of six main stages that rely on the following seven principles (Nicholls et al., 2012):

1. *Involve stakeholders* – Identify stakeholders, who experience changes as a result of a project, and consult them throughout the analysis in the process of determining the project outcomes. Information from stakeholders should be triangulated with the views of other actors (i.e. staff delivering the project) and other third-party research or evidence.
2. *Understand what changes* – Outline well-defined outcomes articulating how the change experienced by each category of stakeholders is created and recognising positive (e.g. increase of pavements might have a positive impact on local shops) and negative (e.g. increase of traffic may create issues to elderly people) changes, as well as intended and unintended ones.
3. *Value the things that matter* - Use financial proxies to estimate the monetary value of outcomes that cannot be easily monetised or are not traded in markets (thus, their value is commonly not recognised), and consider values expressed by different groups of stakeholders.
4. *Only include what is material* - Establish the boundaries of the type of information and evidence that must be included in the accounts of value to give a true and fair picture, or can be materialized (the analysis should be focused only on changes that pass a certain relevance and significance threshold).
5. *Do not over-claim*: The SROI analysis should claim only the change directly caused by the project, as opposed to other factors, to properly calculate the impact, thus taking adequately into account deadweights (i.e. would specific outcomes have happened anyway without the project?), displacement (i.e. what activity would/did the project displace?), attribution (i.e. what external activities also contributed to the change?) and drop off (i.e. does the outcome drop off in future years?).
6. *Be transparent* – Demonstrate the basis to consider the analysis accurate and honest, thus clearly explaining and documenting each decision and assumption, concerning the analysis steps undertaken, indicators, evaluation approaches, and monetary evaluation results, to be reported to the stakeholders.
7. *Verify the result* - Ensure appropriate independent assurance, thus minimising subjectivity. In case of an ex-ante evaluation, the correspondence of the real outputs and outcomes to the forecast should be monitored.

The S.7.1 indicator drwas upon of the afore-mentioned seven principles, and its score, ranging from 0 to 100, is evaluated according to five metrics. Specifically, the evaluation of the first metric concerning the application or not of the SROI analysis to a project leads to the possibility to proceed or not, respectively, with the evaluation of the other four metrics in the form of consecutive statements to which correspond an increasing fixed score per metric whether the corresponding statement is satisfied, as summarised in Table 42.

Table 42. S.7.1 score.

Metric	Score
Select single value from the metrics below:	
The social return on investment (SROI) analysis is **not** applied to the project.	S.7.1 = 0.
The social return on investment (SROI) analysis is applied to the project.	*Check next metrics.*
Check if the consecutive statements are satisfied to select single value from the metrics below:	
Stakeholders have been involved in the project to determine the outcomes of the project.	20
Workshops have **also** been performed to understand the changes experienced by the stakeholders.	50
Changes have **also** been expressed in monetary values (i.e. translating changes into monetary values, also using financial proxies to estimate the monetary value of outcomes that cannot be easily monetised and consider values expressed by different groups of stakeholders).	80
An ex-ante evaluation, which monitors the correspondence of real outputs and outcomes to the forecast, has **also** been performed.	100
Indicator score = one of the potential five metric scores	**S.7.1 = 0, 20, 50, 80 or 100**

Source: JRC.

The five potential scores of the S.7.1 indicator correspond to the indicative thresholds defining the range of each of the four indicative performance classes for S.7.1 (Figure 38). While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 38. S.7.1 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
S.7.1 thresholds ($t_{S.7.1}$):	$0 \leq$	$t_{S.7.1, Acceptable} \geq 20$	$t_{S.7.1, Good} \geq 50$	$t_{S.7.1, Excellent} \geq 80$ ≤ 100

Source: JRC.

3.10.3 Degree of inter-disciplinary integration (S.7.2)

The *degree of inter-disciplinary integration (S.7.2)* indicator assesses the interdisciplinary of a group of professionals/highly skilled workers involved into the project design of a building, a neighbourhood or an urban area in line with the NEB perspective. The S.7.2 indicator is evaluated through the following two metrics:

— *Number of disciplines (ND).*

— *Level of engagement (LE).*

S.7.2 score, ranging from 0 to 100, is calculated as the product of the afore-mentioned two metrics, according to Equation (124).

$$S.7.2 = ND \cdot LE \tag{124}$$

The *number of disciplines (ND)* metric evaluates the diversity of disciplines represented in the group of professionals/highly skilled workers involved in a project. The following potential disciplines, extracted by the subjects of Times Higher Education[22], can be considered: engineering, architecture, spatial planning, physical sciences (e.g. math, biology, physics, chemistry), ecology and environment, agriculture and forestry, computer science and digital technologies, social sciences and humanities arts and culture, health and well being (e.g. Tzoulas et al., 2007; Kolokotsa et al., 2020), economy, policy and governance, law and legislation, administrative experts, other disciplines. General information on the diversity of disciplines can be obtained by counting the number of different educational qualifications that are represented in the group of professionals/highly skilled workers and dividing the result by the total number of professionals/highly skilled workers in the group. However, the evaluation of the ND metric relies on the specific number of different

[22] Times Higher Education: https://www.timeshighereducation.com/world-university-rankings/by-subject

disciplines within the project. The ND score assumes a value equal to 0 or 100 or it results into a value within the range 0-100, depending on three corresponding conditions related to the number of different disciplines, according to Equation (125). In this context, the diversity of disciplines can also be inferred as the ratio of the number of different disciplines and the value of the ND metric, expressed as a percentage.

$$ND = \begin{cases} 0, & for\ No\ of\ different\ disciplines = 0 \\ 100, & for\ No\ of\ different\ disciplines \geq 10 \\ No\ of\ different\ disciplines \cdot 10, & for\ No\ of\ different\ disciplines\ < 10 \end{cases} \quad (125)$$

The *level of engagement (LE)* metric assesses the level of collaboration among the professionals/highly skilled workers from the different disciplines included in a project. Relevant information on the level of collaboration can be directly retrieved by results of existing interviews (if any) with the professionals or by specific documents/reports of meetings/workshops during the project design phase providing data on the degree of interaction among the professionals/highly skilled workers of the project team. LE score is evaluated via a 5-point Likert scale (Joshi et al., 2015), thus resulting into five fixed values depending on the quality of the level of collaboration towards a full engagement among the professionals/highly skilled workers from the different disciplines involved in the project, ranging from very poor to very strong, according to the rationale in Table 43.

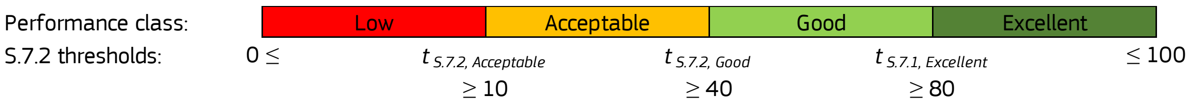
Table 43. Level of engagement metric score.

Sub-metric	**Score**
Select single value from the sub-metrics below:	
Each discipline worked without interaction (i.e. very poor engagement)	0.2
Professionals of some disciplines expressed opinions (i.e. poor engagement)	0.4
Professionals of all disciplines expressed opinions and provided reports (i.e. acceptable engagement)	0.6
Organisation of workshops for the interaction of the professionals of all various disciplines without necessarily reaching a consensus (i.e. strong engagement)	0.8
Engagement among the professionals through workshops and final agreement and consensus (i.e. very strong engagement)	1
Metric score = one of the five sub-metric scores	**LE = 0.2, 0.4, 0.6, 0.8, or 1**

Source: JRC.

The S.7.2 indicative thresholds to associate the S.7.2 indicator score to the indicator performance class are provided in Figure 39. The *Low*, *Acceptable*, *Good*, and *Excellent* indicative performance classes for the S.7.2 indicator correspond to the following ranges of S.7.2 scores, i.e. 0 ≤ S.7.2 < 10, 10 ≤ S.7.2 < 40, 40 ≤ S.7.2 < 80, and 80 ≤ S.7.2 ≤ 100, respectively. While the indicator thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 39. S.7.2 indicative performance classes and thresholds.



Source: JRC.

3.10.4 Gross value added to local economy from new business creation (S.7.3)

The *gross value added to local economy from new business creation* (S.7.3) indicator evaluates the ability of a public entity to stimulate the local economy throughprojects in line with the NEB vision by ensuring that the project development attracts inward investment, creates jobs, and complements and enhances existing economic activities. S.7.3 indicator is fully aligned to the SDG 8 (UN, 2015), which promotes inclusive and sustainable economic growth, full and productive employment, and decent work for all.

The extent of a job creation or destruction can significantly shape the social acceptance and desirability of different interventions related to NEB, also leading to social mobilisation to support or oppose future decarbonisation activities and green transition pathways. Past studies relate the direct and/or indirect contribution of green transition activities and investments in creating possible new jobs, as described in the following. According to Renner at al. (2008), greening the building industry in the EU and the United States would create al least 2 million jobs, which increase to 3.5 million considering a scenario of 75 % CO_2-emission reduction in the residential building sector by 2030. A 2012 analysis (Naess-Schmidt et al., 2012) estimated that the energy renovation of the European building stock could have led to 0.75–1.5 million new jobs per year, if undertaking annual investments of EUR 40 billion until 2020. Similarly, every EUR 1 million investment in the energy efficiency of buildings may correspond on average to 19 new jobs (Jassen and Staniaszek, 2012). Recent studies further stress the link of the possible growth in employment in the EU to the investment needed to meet the green transition goal, leading to the increase of 'green jobs[23]'. Indeed, the green transition will profoundly impact Europe's labour markets: it was estimated that the more ambitious climate target to meet a 55 % reduction in GHG emissions in the EU by 2030, compared with 1990 could lead to a net increase in jobs of up to 884000 by 2030 (Asikainen et al., 2021). Similarly, a recent study (Sovacool et al., 2023) analysed the way one aspect of green transition, i.e. making buildings dependent on self-produced renewable energy, contributes to employment growth in the energy industry, not exploring aggregate job creation within regions/nations or globally, but considering a micro-scale approach assessing job creation at level of individual residential and non-residential buildings equipped with three low-carbon technologies, namely solar PV, batteries for energy storage, heat pumps for the electrification of heating and cooling. Specifically, results pointed out that the largest share of job years derives from construction and installation of the three technologies.

In this context, it is crucial to demonstrate that the implementation of projects in line with the NEB vision may lead to the creation of new green jobs, new businesses, and/orthe improvement of existing working conditions (e.g. higher-paying employment) for a two-fold reason: (*i*) attract investment and funding for the implementation of a specific project and similar future projects, and (*ii*) foster public support for the projects. Indeed, institutional and private investors are increasingly interested in projects that can generate positive social and environmental impacts, and financial returns, as well as citizens are more likely to support projects that clearly benefit their community.

The implementation of a project through its corresponding investment can generate three types of job effects to be estimated: (*i*) direct job effects concern the creation of new jobs, more likely at local level, directly through increased demand of employment for the design and implementation (e.g. via construction, operations, maintenance) of the project and related services, (*ii*) indirect job effects arise in supplier industries of the sustainable economy providing intermediate goods for the project (e.g. green building components, renewable energy technologies, clean mobility, social services, etc.), and (*iii*) induced job effects occur as savings from the project benefits (e.g. reduction of energy consumption) and wage incomes are spent in goods and services generating demand in additional industries. Employment aspects related to salaries and business income may be complemented by introducing weighting parameters to relate them to the local living wage, as Member States in the EU and even regions within the same Member State may have very different living costs. Based on this overview, the following three assumptions are considered to evaluate the S.7.1 score:

1. Every investment of EUR 1 million in projects for the energy renovation of existing buildings can generate 19 new permanent jobs in the building sector (although not at the local level) (Næss-Schmidt et al., 2012).
2. In 2021, the annual average full-time adjusted salary per employee in the EU was estimated equal to EUR 33500 (Eurostat, 2022).
3. A project in line with the NEB vision creates economic value and new jobs with a contract of 3 years per job. If a job foresees a contract less than 3 years, it can be still considered in the counting of jobs for the evaluation of the S.7.3 score, which will be adjusted based on the relevant job contract duration.
4. According to the abovementioned assumption (2) and (3), the monetary value (MV) of one job with a 3-year contract is calculated according to Equation (126) and the result is rounded to a value equal to EUR 100000; consequentially, a monetary value of EUR 1 million corresponds to a maximum number of local jobs with a 3-year contract equal to 10.

[23] Green jobs (International Labour Organization & United Nations, 2016): https://www.ilo.org/resource/article/what-green-job

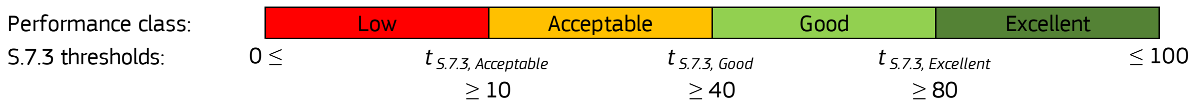
$$MV = Annual\ average\ full\text{-}time\ salary \cdot No\ of\ years\ of\ contract = 33500\ \frac{€}{year} \cdot 3\ years = 100500\ € \approx 100000\ € \quad (126)$$

S.7.3 score is calculated according to Equation (127) as the ratio of the monetary value of the jobs created by the project to the total monetary budget of the project; multiplied by 100, so that the score can be expressed as a dimensionless value ranging from 0 to 100.

$$S.7.3 = \frac{MV\ per\ job\ \left[\frac{€}{job}\right] \cdot No\ of\ 3\text{-}year\ contract\ jobs\ created\ by\ the\ project\ [jobs]}{Total\ budget\ of\ the\ project\ [€]} \cdot 100 \quad (127)$$

The S.7.3 indicative thresholds to associate the indicator score to the indicator performance class are provided in Figure 40. The *Low*, *Acceptable*, *Good*, and *Excellent* indicative performance classes for the S.7.3 indicator correspond to the following ranges of S.7.3 scores, i.e. 0 ≤ S.7.3 < 10, 10 ≤ S.7.3 < 40, 40 ≤ S.7.3 < 80, and 80 ≤ S.7.3 ≤ 100, respectively. While the indicator thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 40. S.7.3 indicative performance classes and thresholds.



Source: JRC.

3.10.5 Example (S.7)

An investment of EUR 15 million is provided by public entities for a renovation project of a brownfield urban site into an area with residential buildings and green spaces. A total number of 50 members constitutes the team of professionals/highly skilled workers involved in the project design and the number of different disciplines within the team equals to 5. Moreover, the level of collaboration among the team members of the different disciplines during the design of the intervention is based on relevant information directly reported by the team members. The neighbourhood scale project was in open consultation with the local inhabitants, and one workshop was performed to present the project. The investment also creates jobs in the construction, remediation, and landscaping sectors. The construction sector implies energy efficiency and renewable energy skills, leading to jobs in retrofits, installations, and maintenance. Moreover, a new public transportation line is added, potentially creating one additional job at least in operation phase. The new green space and parks can also create two jobs in maintenance and management of socio-cultural-motorial activities. In addition to the benefits provided by the creation of these direct jobs, the project can lead to the creation of indirect jobs by supporting local businesses and attracting new businesses to the area. Assuming that an economic analysis based on local data shows the lack of restaurants in the designated area of the project, the regenerated neighbourhood may attract restaurants, cafes, and grocery shops to satisfy the needs of new residents, thus creating new indirect jobs related to food service and hospitality. Specifically, 12 new direct jobs with a 3-year contract each have been created at local level.

The evaluation of the S.7 KPI to achieve the possible greening of the public sector depends on the scores of S.7.1, S.7.2, and S.7.3 indicators.

The **S.7.1 score** is estimated according to the metrics in Table 42. S.7.1 score is based on the application of the SROI anlysis to the project, thus leading two out of four metrics in the form of consecutive statements to be satisfied, as reported in Table 44. Indeed, stakeholders, namely the residents of the neighbourhood area, who also participate to the workshop to present the project, were involved into the project analysis; whereas changes resulting from the project were not expressed in monetary values and a forecast SROI was not performed. The S.7.1 score, resulting into a value equal to 50, corresponds to the indicative Acceptable performance class (Figure 38).

Table 44. Example of S.7.1 evaluation.

Metric	**Score**
The social return on investment (SROI) analysis is applied to the project.	*Check next metrics.*
Stakeholders have been involved in the project to determine the outcomes of the project. Workshops have **also** been performed to understand the changes experienced by the stakeholders.	20 50
Indicator score = one of the potential five metric scores	**S.7.1 = 40**

Source: JRC.

The evaluation of **S.7.2 score** relies on the following two metrics: (*i*) number of disciplines (ND), and (*ii*) level of engangement (LE).

The *ND* metric is evaluated by using Equation (125) according to the third condition indicated in that equation, as the number of different disciplines equals 5. Hence, ND score is estimated equal to 50 (Equation (128)), as follows:

$$ND = 5 \cdot 10 = 50, \quad for\ No\ of\ different\ disciplines = 5 < 10 \tag{128}$$

The *LE* metric is estimated according to the sub-metrics in Table 43, leading to an acceptable quality of the engagement among professionals/highly skilled workers of all disciplines considered within the project, as they expressed opinions and provided reports during the project design phase.Thus, the LE score equals to 0.6.

From Equation (124), the score of the S.7.2 indicator is estimated equal to 30 (Equation (129)). Accordingly, the S.7.2 score is associated to the indicative Acceptable performance class (Figure 39).

$$S.7.2 = 50 \cdot 0.6 = 30 \tag{129}$$

The **S.7.3 score** is estimated by using Equation (127), considering that the monetary value per job is equal to EUR 100000 and the total budget of the project corresponds to the investment of EUR 15 million. Hence, S.7.3 score is estimated equal to 8 (Equation (130)), which corresponds to an indicative Low performance class for S.7.3 indicator (Figure 40).

$$S.7.3 = \frac{100000\ €/job\ \cdot 12\ jobs}{15000000\ €} \cdot 100 = 8 \tag{130}$$

Having evaluated the scores of S.7.1, S.7.2, and S.7.3 indicators, S.7 is evaluated by using Equation (123), resulting into a score equal to 23 that corresponds to the *Acceptable* performance class (Figure 37), as reported in Table 45.

Table 45. Example of S.7 evaluation.

Indicator	**S.7.1**	**S.7.2**	**S.7.3**
Indicator score	50	30	8
Indicator performance class (indicative) [1]	(Acceptable)	(Acceptable)	(Low)
S.7 score	0.2 • 50 + 0.3 • 30 + 0.5 • 8 = 23		
S.7 performance class	Acceptable		
S.7 performance class score ($PCS_{S.7}$)	45		

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

3.11 Achieve the best possible greening of the private and financial sector in terms of its economic involvement in the sustainability of the built environment (S.8)

3.11.1 Description and assessment

Achieve the possible greening of the private and financial sector in terms of its economic involvement (S.8) KPI is assessed through the following two indicators:

— *Green financial tools (S.8.1).*

— *Compliance with ESG standards and European Sustainability Reporting Standards (ESRS) for green transition investments from private companies (S.8.2).*

In the **general case** when both indicators are considered, S.8 score is evaluated according to Equation (131).

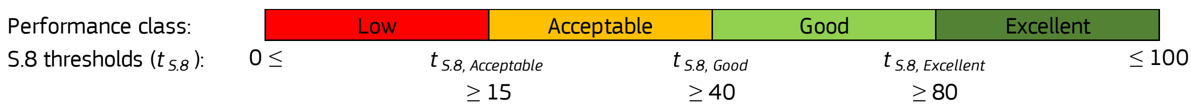
$$S.8 = \sum_{j=1}^{2}\left(w_{S.8.j} \cdot S.8.j\right) \Big/ \sum_{j=1}^{2}\left(w_{S.8.j}\right) = 0.5 \cdot S.8.1 + 0.5 \cdot S.8.2 \qquad (131)$$

Specifically, S.8.2 indicator is evaluated only when the European Sustainability Reporting Standards (ESRS) are mandatory for use by at least one private company (involved in the project) that is obliged by the Corporate Sustainability Reporting Directive (CSRD) (Directive, 2022) to report specific sustainability information on its performance. Accordingly, **if no private company involved in the project is obliged by the CSRD** (Directive, 2022) **to use the ESRS to fulfill sustainability reporting obligations**, S.8.2 is omitted and S.8 score is evaluated according to Equation (132).

$$S.8 = \sum_{j=1}^{2}\left(w_{S.8.j} \cdot S.8.j\right) \Big/ \sum_{j=1}^{2}\left(w_{S.8.j}\right) = 1 \cdot S.8.1 \qquad (132)$$

S.8 thresholds to associate the KPI score to the performance class adopted in the self-assessment method are provided in Figure 41. The *Low, Acceptable, Good,* and *Excellent* performance classes of S.8 correspond to the following ranges of S.8 scores, i.e. 0 ≤ S.8 < 15, 15 ≤ S.8 < 40, 40 ≤ S.8 < 80, and 80 ≤ S.8 ≤ 100, respectively.

Figure 41. S.8 performance classes and thresholds.



Source: JRC.

S.8 and its two associated indicators can be applied at building, neighbourhood and urban scale, including both newbuild and renovation projects with both residential and non-residential main use.

3.11.2 Green financial tools (S.8.1)

The *green financial tools (S.8.1)* indicator refers to special terms, incentives, or benefits for a project that traditional financial instruments do not provide. The indicator recognises and measures the extent of the use of private green financial tools over the total private funding used for a project, helping in understanding the financial health and strategy of the project, while mainstreaming the green finance. The more a NEB project adopts and showcases the use of green financial tools, the more normalized these tools become in the industry and can assist in the greening of the private and financial sector. Additionally, S.8.1 indicator through the specific focus on green financing, can spur further innovation in sustainable technologies and practices, as there is a clear financial incentive to adopt them.

S.8.1 score is evaluated as the ratio of private green funding tools (i.e. examples of green financial instruments are defined in Table 2) used for a project to the total private funding, multiplied by 100, so that S.8.1 score can be expressed as a dimensionless value that ranges from 0 to 100, according to Equation (133).

$$S.8.1 = \frac{Private\ green\ funding\ tools\ and\ mechanisms\ used\ for\ the\ project\ [€]}{Total\ private\ funding\ of\ the\ project\ \ [€]} \cdot 100 \qquad (133)$$

S.8.1 indicative thresholds to associate the indicator score to the corresponding indicator performance class are provided in Figure 42. The *Low, Acceptable, Good,* and *Excellent* performance classes of S.8.1 correspond to the following ranges of S.8.1 scores, i.e. 0 ≤ S.8.1 < 15, 15 ≤ S.8.1 < 40, 40 ≤ S.8.1 < 80, and 80 ≤ S.8.1 ≤ 100, respectively. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 42. S.8.1 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
S.8.1 thresholds ($t_{S.8.1}$):	$0 \leq$		$t_{S.8.1,\ Acceptable} \geq 15$		$t_{S.8.1,\ Good} \geq 40$		$t_{S.8.1,\ Excellent} \geq 80$		≤ 100

Source: JRC.

3.11.3 Compliance with ESG standards and European Sustainability Reporting Standards for green transition investments from private companies (S.8.2)

The *compliance with ESG standards and ESRS for green transition investments from private companies (S.8.2)* indicator evaluates how private companies involved into a project to be self-assessed deal with the green transition investments in other projects to further stimulate green/sustainable financing tools and a sustainable economy. The S.8.2 indicator is evaluated only if at least one of the private companies involved in the project to be self-assessed is obliged by the CSRD to follow the requirements for its sustainability performance reporting, according to the European Sustainability Reporting Standards (ESRS). Indeed, the CSRD requirements and obligations for companies' sustainability reporting according to the ESRS, including the EU Taxonomy alignment are integral to the EU's strategic plan to achieve climate neutrality by 2050 and to foster a sustainable economic framework. The ESRS (Baumüller and Grbenic, 2021; Giner and Luque-Vílchez, 2022) targets to enhance the scope and quality of corporate sustainability reporting, while promoting sustainable development through increased transparency. Stakeholders, particularly investors, other businesses, and society at large, should have access to better insights into companies' business practices. The ESRS require companies to provide detailed information about their sustainability performance, sometimes extending all the way to the supply chain and product life cycle. Specifically, the shift from 'non-financial' (Directive, 2014) to 'sustainability' reporting demands more robust data management and the refinement of existing reporting structures and processes, particularly since the CSRD mandates an electronic format for sustainability data. Notably, companies governed by the CSRD are not required to produce a separate sustainability report compliant with the ESRS; rather, sustainability information is integrated into the groups' annual report. Importantly, the sustainability reporting is also subject to external audit requirements. Companies must be prepared to explain how specific environmental, social, and governance data are collected. Overall, the ESRS enhances the quality and comparability of reporting content. However, the implications of the ESRS extend beyond mere reporting mandates. These standards also require companies to disclose improvements in their sustainability performance and advancements in sustainability management. Ultimately, these requirements aim to hasten the transition towards a sustainable economy.

The CSRD identifies the companies that are required to publish the annual report on their social and environmental performance, according to the ESRS, along with the fiscal year the corresponding companies have to apply the new rules for the first time, as follows (Directive, 2022):

— From fiscal year 2024 (firstreports published in 2025): companies that are already subject to a reporting obligation under the Non-Financial Reporting Directive (Directive, 2014).

— From fiscal year 2025 (first reports published in 2026): all other large corporations with an annual average of 250 employees or more, total assets of 25 million euros or EUR 50 million in sales. Two of these three criteria must be met for a company to fall within the scope of the CSRD.

— From fiscal year 2026 (first reports published in 2027): listed SMEs, small and non-complex credit institutions, and captive insurance companies.

— From fiscal year 2028 (first reports published in 2029): third-country companies with subsidiaries or branches in the EU that generate a net turnover of more than EUR 150 million in the Union for two consecutive financial years.

The S.8.2 indicator is evaluated only if the following statement is satisfied for at least one of the private companies involved into a project:

— *At least one of the private companies involved into the project is under the scope of the CSRD to mandatory fulfill sustainability reporting obligations, according to ESRS.*

If this statement is satisfied, the S.8.2 indicator is evaluated through the two following metrics:

— *Total own funding investments (Total OFI).*

— *Total green investments (Total GI).*

The S.8.2 score is estimated as the ratio of the *Total GI* metric to the *Total OFI* metric, multiplied by 100, so that S.8.2 score is expressed as a dimensionless valuethat ranges from 0 to 100, according to Equation (134).

$$S.8.2 = \frac{Total\ GI\ \ [€]}{Total\ OFI\ [€]} \cdot 100 \tag{134}$$

The *Total GI* metric is estimated as the sum of the green investment of the i-th company involved in the project, according to Equation (135), in which N is the total number of the private companies involved in the project.

$$Total\ GI\ = \sum_{i=0}^{n} GI_i\ \ [€] \tag{135}$$

The *Total OFI* metric is estimated as the sum of the own funding investment of the i-th company involved in the project, according to Equation (136), in which N is the total number of private companies involved in the project.

$$Total\ OFI\ = \sum_{i=0}^{n} OFI_i\ [€] \tag{136}$$

The S.8.2 thresholds to associate the indicator score to its corresponding performance classare are provided in Figure 43. The *Low, Acceptable, Good,* and *Excellent* indicative performance classes of S.8.2 correspond to the following ranges of S.8.2 scores, i.e. 0 ≤ S.8.2 < 15, 15 ≤ S.8.2 < 40, 40 ≤ S.8.2 < 80, and 80 ≤ S.8.2 ≤ 100, respectively. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 43. S.8.2 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
S.8.2 thresholds ($t_{S.8.2}$):	0 ≤		$t_{S.8.2,\ Acceptable}$ ≥ 15		$t_{S.8.2,\ Good}$ ≥ 40		$t_{S.8.2,\ Excellent}$ ≥ 80		≤ 100

Source: JRC.

3.11.4 Example (S.8)

An investment of EUR 15 million in the redevelopment of a brownfield urban site into residential buildings and green spaces is considered. The consortium of investors includes three private companies, specifically consisting of two private manufacturers and one consultancy private company, hereinafter indicated as company 1, company 2, and company 3, respectively. A private green funding equal to EUR 3 million is ensured via green bonds and other green financing tools for the project development, whereas the total private funding for the project corresponds to 50 % of the investment, thus being equal to EUR 7.5 million. Beyond the redevelopment project above, two out of the three private companies have also invested in other green projects. Specifically, company 1, which is one out of the two private manufacturers, has invested own funds equal to EUR 500000 in the project and invested in green transition with EUR 100000 in photovoltaics in their office building. Company 2, corresponding to the other private manufacturer, has invested EUR 1 million in a new property with its own funds. Company 3 that refers to the consultancy company has invested EUR 200000, which represents the 20 % of its own funding scheme, in a circular economy start-up company.

The evaluation of S.8 KPI depends on the evaluation of S.8.1 and S.8.2 indicator scores, as the ESRS apply mandatory to all three companies involved into the project, according to CSRD.

The **S.8.1 score** is evaluated by using Equation (133), resulting into a value equal to 40 (Equation (137)). Accordingly, the S.8.1 score is associated to the indicative Good performance class (Figure 42).

$$S.8.1 = \frac{3000000\ €}{7500000\ €} \cdot 100 = 40 \tag{137}$$

The **S.8.2 score** relies on the rationale that the following statement needs to be satisfied: *the private company involved in the project is under the scope of the CSRD to mandatory fulfill sustainability reporting obligations, according to ESRS.* All the three private companies involved into the project satisfy the statement, thus the S.8.2 score can be evaluated based on the two following metrics: *(i)* total own funding investiment (Total OFI), and *(ii)* total green investment (Total GI).

The *Total OFI* metric is estimated by using Equation (136), considering the OFI of each of the three companies, as follows (Equation (138)):.

$$Total\ OFI = 500000 + 1000000 + 1000000 = \ 2.5\ million\ € \tag{138}$$

The *Total GI* metric is estimated by using Equation (135), considering the GI of the company 1 and 3 (company 2 has not invested in green projects), as follows (Equation (139)):

$$Total\ GI = 100000 + 200000 = \ 300000\ € \tag{139}$$

The evaluation of S.8.2 score is carried out by using Equation (134), thus resulting into a value equal to 12, according to Equation (140). Accordingly, the S.8.1 score is associated to the indicative Low performance class (Figure 43).

$$S.8.2 = \frac{300000\ €}{2500000\ €} \cdot 100 = 12 \tag{140}$$

Having evaluated the scores of S.8.1 and S.8.2 indicators, S.8 score is calculated by using Equation (131), resulting into a valueequal to 26 that corresponds to the *Acceptable* performance class (Figure 41), as summarised in Table 46.

Table 46. Example of S.8 evaluation.

Indicator	**S.8.1**	**S.8.2**
Indicator score	40	12
Indicator performance class (indicative) [1]	(Good)	(Low)
S.8 score	0.5 • 40 + 0.5 • 12 = 26	
S.8 performance class	Low	
S.8 performance class score (PCS_{S8})	25	

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

3.12 Promote circular economy in the built environment (S.9)

3.12.1 Description and assessment

Promote circular economy in the built environment (S.9) KPI aims to point out the rate of using secondary and/or bio-based and/or recycled materials in the construction industry, contributing to close the circularity loop of materials through the use of less impactful and more regenerative materials. In this context, the circular economy in the built environment deals with re-used, recycled and renewable construction materials. The re-use of materials or components, according to the standard ISO 20887 (ISO, 2020), more than once for the same or other purposes without reprocessing (it does not include cleaning, trimming, connectors removal, coatings removal, etc.) can extend the lifetime of building elements and/or buildings. The recycle of materials and/or components to be separated and reprocessed from constructions products and systems to be subsequently used as material input for the same or different use or function is also a vital process to reduce the construction and demolition waste. A material is recyclable, if it can be diverted from the waste stream and, through existing processes, facilities, and markets, returned to the economy. Finally, recovery means the restoration of materials found in the waste stream to a beneficial use which may be for purposes other than the original use. The use of renewable materials, such as wood, and new value chains based on biomass from forests, agriculture and organic waste, is particularly advantageous in the construction chain since these materials are inherently regenerative. Furthermore, the potential re-use and recycling of renewable materials has also environmental and climate benefits (Fayolle, 2022). The EU encourages the use of sustainable materials, such as recycled concrete and energy-efficient insulation, to cut emissions associated with construction. Increasing the EU circular material use rate (CMUR), which refers to the share of the total amount of material used in the EU-27 coming from recycled waste materials, can reduce the use of natural resources and extracted materials and minimise the negative environmental and economic impacts.

S.9 is evaluated through one main indicator, as follows:

— *Secondary, bio-based, recycled materials (S.9.1).*

S.9 score, ranging between 0 and 100, is calculated according to Equation (141), thus corresponding to S.9.1 score.

$$S.9 = (w_{S.9.1} \cdot S.9.1)/w_{S.9.1} = 1 \cdot S.9.1 \quad (141)$$

The S.9 thresholds adopted in the self-assessement method to associate the KPI score to the KPI performance classare provided in Figure 44. The *Low, Acceptable, Good,* and *Excellent* performance classes of S.9 correspond to the following ranges of S.9 scores, i.e. 0 ≤ S.9 < 10, 10 ≤ S.9 < 40, 40 ≤ S.9 < 80, and 80 ≤ S.9 ≤ 100, respectively.

Figure 44. S.9 performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
S.9 thresholds ($t_{S.9}$):	0 ≤	$t_{S.9, Acceptable} \geq 10$	$t_{S.9, Good} \geq 40$	$t_{S.9, Excellent} \geq 80$; ≤ 100

Source: JRC.

S.9 and its associated indicator can be applied at all the three spatial scales of a project (i.e. building, neighbourhood, and urban), including both newbuild and renovation projects with residential and non-residential use.

3.12.2 Secondary, bio-based, recycled material (S.9.1)

Secondary, bio-based, recycled material (S.9.1) is based on the circularity indicator proposed into the recent standard ISO 59020 (ISO, 2024c), as well as on the material circularity indicator within the 'Circular Transition Indicator' framework developed by the World Business Council for Sustainable Development (WBCSD, 2022b). Accordingly, the S.9.1 indicator measures the circularity of materials within a project by considering the share of secondary, bio-based and recycled materials in relation to the total amount of materials used in a project, thus S.9.1 is evaluated through the following metric:

— *Circularity of material (CM).*

S.9.1 score is estimated as the product of the CM metric by both a constant k *(i.e. $k = 5$)* and 100, so that the indicator score is expressed as a dimensionless value that varies between 0 and 100, according to Equation (142).

$$S.9.1 = CM \cdot k \cdot 100 \tag{142}$$

The *Circularity of material (CM)* score is calculated as the ratio of the mass of secondary, bio-based and recycled materials used in a building/neighbourhood/urban project to the total mass of the total amount of materials used in the project, expressed as a percentage, according to Equation (143).

$$CM = \frac{Mass\ of\ secondary, bio\text{-}based\ and\ recycled\ materials\ in\ the\ project\ [tons]}{Total\ mass\ of\ materials\ used\ in\ the\ project\ [tons]} \cdot 100\ [\%] \tag{143}$$

In the Equation (142), the value of the constant k is based on the EU CMUR target by 2030. Specifically, the CMUR, which refers to the share of the total amount of material used in the EU-27 coming from recycled waste materials, is quite low with the recycled material accounting for 11.5 % of total material used in 2022 (Eurostat, 2023f), although this figure demonstrates a slow progressive increase of the CMUR that was estimated equal to 10.7 % in 2010. The 2022 figure should increase to 23.2 % by 2030 to meet the target of doubling the CMUR compared to the 2020 rate (COM, 2020a). Based on this projection, the S.9.1 score evaluation relies on the assumption that the maximum value of CM (CM_{max}) is equal to 20 %, thus CM score ranges between 0 % and 20 %. According to this assumption, CM_{max} needs to be multiplied by a constant that results into a value equal to 5 to achieve the S.9.1 maximum score equal to 100 (i.e. $S.9.1 = CM_{max} \cdot k \cdot 100 \rightarrow 100 = 20 \cdot k \rightarrow k = 5$). In the case of the CM score being higher than 20 %, the S.9.1 score cannot exceed 100.

The indicative thresholds to associate the S.9.1 indicator score to the indicator performance classes are provided in Figure 45 for sake of completeness since the S.9.1 thresholds correspond to the S.9 ones, as expected. The *Low, Acceptable, Good,* and *Excellent* performance classes for the S.9.1 indicator correspond to the following ranges of S.9.1 scores, i.e. 0 ≤ S.9.1 < 10, 10 ≤ S.9.1 < 40, 40 ≤ S.9.1 < 80, and 80 ≤ S.9.1 ≤ 100, respectively. While the indicator thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 45. S.9.1 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
S.9.1 thresholds ($t_{S.9.1}$):	0 ≤		$t_{S.9.1,\ Acceptable}$ ≥ 10		$t_{S.9.1,\ Good}$ ≥ 40		$t_{S.9.1,\ Excellent}$ ≥ 80		≤ 100

Source: JRC.

3.12.3 Example (S.9)

A building with a total floor area equal to 4000 m^2 and its surrounding area equal to 5 acres is refurbished following the NEB concept. A circular economy strategy is adopted by re-using all secondary concrete and stone materials to build the courtyard and the pedestrian paths around the building. The mass of secondary, bio-based, recycled materials used in the project is equal to 500 tonnes. The total mass of materials used in the project is estimated to be 12500 tonnes.

The evaluation of S.9 depends on S.9.1 score, which relies on the CM metric. The CM score is calculated by using the Equation (143), thus estimating that 4 % of the total amount of material used in the project comes from secondary, bio-based, recycled materials, as follows (Equation (144)):

$$CM = \frac{500\ \text{tonnes}}{12500\ \text{tonnes}} \cdot 100 = 4\ \% \tag{144}$$

Accordingly, the **B.9.1 score** is evaluated from Equation (142), as follows (Equation (145)):

$$S.9.1 = 4\ \% \cdot 5 \cdot 100 = 20 \tag{145}$$

Having evaluated the S.9.1 score, the **S.9 score** is calculated by using Equation (141), thus resulting into a value equal to 20, thus corresponding to the *Acceptable* performance class (Figure 44), as reported in Table 47.

Table 47. Example of S.9 evaluation.

Indicator	**S.9.1**
Indicator score	20
Indicator performance class (indicative)	(Acceptable)[1]
S.9 score	= 1 · 20 = 20
S.9 performance class	Acceptable
S.9 performance class score ($PCS_{S.9}$)	45

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

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List of abbreviations and definitions

ABS	Asset-Backed Securities
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
A_u	Useful internal floor area (m^2)
B	Benefit
B/C	Cost-Benefit Ratio
BEMS	building energy management system
BMS	building management system
BoM	Bill of materials
BoQ	Bill of quantities
BRT	Bus rapid transit system
C	Cost
$C_{pollutant}$	Air pollutant concentration level
CAMS	Copernicus Atmosphere Monitoring Service
CBA	Cost-Benefit Analysis
CBC	Circular Building Coalition
CBI	Climate Bond Initiative
CDD	Cooling degree days
CDW	Construction and demolition waste
CDWR	quantity of construction and demolition waste that can be recovered for reuse by recycling at the end of the life cycle of a building
CDWT	total construction and demolition waste generated at the end of the life cycle of a building
CE	Circular Economy
CEA	Cost-Effectiveness Analysis
CEF	Circle Economy Foundation
CEN	Comité Européen de Normalisation
CHP	Combined heat and power
CH_2O	Formaldehyde
CM	Circularity of material
CMRRR	mass quantity of all the reused, recycled, and renewable construction materials/products
CMT	total construction materials utilized in a project
CMUR	Circular material use rate
CO	Carbon monoxide
CO_2	Carbon dioxide
CS	Carbon stock
CSEQ	Carbon sequestration
CSR_i	CO_2 stock ratio of the i-th ecosystem on land
CSRD	Corporate Sustainability Reporting Directive
CDW	Construction and demolition waste
CDW_G	Generated construction and demolition waste
CDW_R	Recovered construction and demolition waste
DBA	Degree of built area
DHW	Domestic hot water
DNSH	Do No Significant Harm principle
DPBP	Discounted Payback period
EBITDA	Earnings Before Interest, Tax, Depreciation, and Amortization
E_c	Annual delivered electrical energy demand
$E_{del,i}$	delivered energy for energy carrier i

EEA	European Environment Agency
E_e	Annual delivered electrical energy demand (exported energy)
$E_{exp,i}$	exported energy for energy carrier i
$EGHG_b$	Embodied greenhouse gas emissions of building
E_i	Annual delivered electrical energy demand (imported energy)
EMDE	Emerging markets and developing economies
E_P	Annual delivered electrical energy demand produced by on-site plants
$E_{P,max}$	Maximum electrical power supplied to a building
$E_{P;Ause;a}$	annual primary energy demand intensity of a building
EPBD	Energy Performance of Buildings Directive
EPC	Energy performance certificate
EPD	Environmental product declaration
$EP_{t,es}$	Energy supplied by an energy storage at time step (t)
E_{rep}	reported emissions (simulated or/and measured accordingly for new or existing buildings) of air pollutants
E_{RES}	Annual delivered electrical energy demand covered by renewable energy sources
$E_{t,RES}$	Annual total delivered energy demand (including both electricity and thermal energy) for building operations covered by renewable energy sources
ESG	Environmental, social, and governance
ESRS	European Sustainability Reporting Standards
ETS	Emissions Trading System
EU	European Union
EU-27	27 European Union Member States
EurEau	European Federation of National Associations of Water Services
EV	Electric vehicle
FR	Flexibility requirements
FR^T	Flexibility requirements over the time period (T)
$FR^{T,es}$	Contribution of the energy storage to the flexibility requirements at a specific timescale (T)
GFT	Green Financial Tools
GHG	Greenhouse gas
GI	Green investments
GWP	Global Warming Potential
GWP-total	Global Warming Potential (i.e. embodied GHG emissions) of construction products
$GWP\text{-}total_b$	Global Warming Potential (i.e. embodied GHG emissions) of a building
HDD	Heating degree days
I(d,ic)	score of domain number d for impact criterion ic for the assessment of smart readiness of a building
IAQ	Indoor air quality
ICER	Incremental Cost-Effectiveness Ratio
IDI	Degree of Interdisciplinary Integration
$I_{max(d,ic)}$	maximum score of domain number d for impact criterion number ic for the assessment of smart readiness of a building
IPCC	Intergovernamental Panel of Climate Change
IRR	Internal Rate of Return
ISO	International Organisation for Standardisation
IWEC	international weather for energy calculation
IWBI	International Well Building Institute
$k_{em,}$	Greenhouse gas emissions factor
$k_{em,dhc}$	Greenhouse gas emissions factor of energy from district heating/cooling, GHG emissions per unit energy

$k_{em,el}$	Greenhouse gas emissions factor for electricity form the grid, GHG emissions per unit energy
$k_{em,i}$	Greenhouse gas emissions factor, GHG emissions per unit energy of an i-fuel
$KgCO_2/m^2/y$	Kilograms of carbon dioxide per square meter per year
L/o/d	Litre per occupant per day
LBPL	Total length of bicycle paths and lanes
LCA	Life Cycle Assessment
LE	Level of engagement
LPT	Total length of public transport systems
MDB	Multilateral development banks
MEC	Minimal Environmental Criteria
$MtCO_2eq$	Million tonnes of carbon dioxide equivalent
Mtoe	Million tonnes of oil equivalent
MV	Monetary value
n	design value for the number of persons in a room
NBPS	Number of available indoor and/or outdoor bicycle parking spaces of a building
ND	Number of disciplines
NDW	Number of dwellings
NEB	New European Bauhaus
NEV	Total number of electric vehicles
NFRD	Non-Financial Reporting Directive
NI	Total number of inhabitants living within 0.5 km of public transit running at least every 20 min during peak periods
NO_2	Nitrous dioxide
NPS	Total number of car parking spaces serving a building
NPTT	Total number of public transport trips
NPV	Net present value
NRP	Total number of car parking spaces served by a recharging point for electric vehicles with a power output greater than 3.7 kW
NRS	Total number of recharging stations for electric vehicles
Nsm	number of buildings in an urban area with smart energy meters
Nt	total number of buildings in an urban area
NTT	total annual number of public transport trips originating in an area (ridership of public transport)
NZEB	Nearly zero-energy building
OFI	Own Funding Investments
OGHG	Operational greenhouse gas emissions of a building per unit floor area
P	Population, i.e. total number of inhabitants in an area
PEB	positive energy buildings
$PEF_{P,del,i}$	Primary energy factor for the delivered energy carrier i
$PEF_{P,exp,i}$	Primary energy factor for the exported energy carrier i
PM	Particulate matter
PM10	particulate matter with a diameter of 10 micrometers or less
PM2.5	particulate matter with a diameter of 2.5 micrometers or less
PPP	Public-private partnership
PWC	Daily potable water consumption per occupant for all water uses, appliances and sanitary fittings/devices in a building
Q	Annual delivered energy per energy carrier
q_B	Ventilation rate for emissions from building materials
Q_c	Annual delivered thermal energy demand
Q_{dhc}	Total quantity of annual energy from district heating/cooling

Q_e	Annual delivered thermal energy demand (exported energy)
Q_{el}	Total quantity of annual electrical energy from the grid
$Q_{fuel,i}$	Total annual delivered energy from the i-th fuel used for the specific technical building systems
Q_i	Annual delivered thermal energy demand (imported energy)
Q_p	Annual delivered thermal energy demand produced by on-site plants
q_p	ventilation rate for occupancy per person
Q_{RES}	Annaul delivered thermal energy demand covered by renewable energy sources
q_{tot}	Total ventilation rate for the breathing zone
r	Discount rate
RED	Renewable Energy Directive
RES	Renewable energy sources
RES_{tot}	Share of renewable energy, relative to total delivered energy demand for building operations
RL_t	Residual load at each time step (t) within a time period (T), which is the delivered energy consumption minus energy locally produced by renewable energy sources
Rn	Radon
S_a	Total surface of a designated urban area
$S_{a,1}$	Surface of developed areas within a designated urban area
$S_{a,2}$	surface of undeveloped areas within a designated urban area
$S_{a,i}$	i-th different surface type within a designated urban area
$S_{a,perm}$	Surface of the real permeability of the soil of the designated urban area
SC	Subcommittee
SCRAM	support center for regulatory atmospheric modeling
SDG	Sustainable development goals
SME	Small and medium size enterprise
SPO	Second Party Opinion
SR	Smart readiness
SRd,ic	smart readiness scores of technical domains for each impact criterion
SRf	smart readiness score for key functionality f
SROI	Social Return on Investment
T	Project lifetime
$T_{baseline}$	Threshold assigned to the minimum value of an indicator
TC	Techinal Committee
tCO_2/ha/y	Tonnes of carbon dioxide per hectare per year
TWh	Terawatt hours
UC	Total user capacity of a non-residential building
UN	United Nations
UNEP	United Nations Environmental Programme
US EPA	United States Environmental Protection Agency
USD	United States dollar
V2G	vehicle-to-grid
V2H	vehicle-to-home
VOC	Volatile organic compound
WBCSD	World Business Council for Sustainable Development
WGBC	World Green Building Council
Wf	weight of key functionality f in the estimation of the total smart readiness scores
XPS	Extruded polystyrene
Z	Climate zone
α_i	Permeability weighting factor of surface type-i

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Annex A Supplement to Chapter 3

Table A.1. Relevant reports concerning developments on circular economy in the built environment, with reference to the period 2018-2023.

Organisation body	Title	References
Circular Buildings Coalition (CBC)	*Towards a circular economy in the built environment - Overcoming market, finance and ownership challenges*	CBC, 2023
World Green Building Council (WGBC)	*The circular built environment playbook*	WGBC, 2023
Circular City Centre (C3) and Circle Economy	*A guide for circularity in the urban built environment*	C3 and Circle Economy, 2023
World Business Council for Sustainable Development (WBCSD)	*Measuring Circular economy – key considerations*	WBCSD, 2022a
World Business Council for Sustainable Development (WBCSD)	*Circular Transition Indicators V3.0 - Metrics for business, by business*	WBCSD, 2022b
World Business Council for Sustainable Development (WBCSD)	*The business case for circular buildings - Exploring the economic, environmental and social value*	WBCSD, 2021
ARUP and Ellen MacArthur Foundation	*From principles to practices: realising the value of circular economy in real estate*	ARUP and Ellen MacArthur Foundation, 2020
World Business Council for Sustainable Development (WBCSD)	*Circular Metrics – Landscape Analysis*	WBCSD, 2018

Source: JRC.

Chapter 4: Beauty

4 Beauty

4.1 How to achieve a high level of beauty in the built environment

The New European Bauhaus (NEB) paradigm (COM, 2021a) identifies, within the dimension of Beauty, two primary requirements for the built environment: ensuring an adequate quality of experience for the users and presenting a pleasant level of aesthetics and style that transcends functionality. This revisits the principles of Vitruvian tradition, wherein architecture was regarded as a reflection of nature, and where aesthetic quality (*venustas*), stability (*firmitas*) and utility (*utilitas*) stood as its fundamental attributes.

Research indicates that the aesthetic component of the Beauty dimension is a desirable element of the human living environment (Coburn et al., 2017). In the past, the prevailing view was that the visual aspect of beauty in architecture results from the perfect construction of a building, being a function of the proportions of the parts and their relationship to the whole. In this approach, beauty could be "measured". Changes in the definition of aesthetic quality were brought by modern empiricism, which assumed that since we are born without innate ideas about beauty, we can only judge it based on our own experiences — pleasure or lack thereof. Some empiricists believed that its evaluation could only be subjective, while others pointed out that it could be treated in universal terms, since people have common experiences that influence their judgements (Tatarkiewicz, 1980).

In the past century, beauty as an aesthetic category has lost its importance. In the wave of modernism, there was a paradigm shift in architecture ('form follows function'), and the discussion of beauty was also hampered by postmodern anti-aesthetics concepts. Since the 1990s, the academic discourse has called for a 'reclaiming' of beauty, even though this is often seen as an ideological statement, usually conservative. However, aesthetics is neither an ideological nor a political issue, even though it may relate to the local values and cultural ideals of a community (van Damme, 1996). Aesthetics concerns the relationship between object and subject in a particular situation or environment (Sartwell, 2004). Aesthetic quality is a kind of matching function between form and its context. Moreover, it is nowadays presented as one of the conditions for human wellbeing, and even as an element necessary for the health and survival of our species. This underscores the necessity for a comprehensive evaluation of these aspects within a common unified dimension.

There is a need to draw the attention of designers to issues of beauty in the built environment and to support solutions that go hand in hand with EU policies. Achieving beauty in the built environment should be a conscious pursuit and an explicitly declared objective of place-making, planning or building (European Commission, 2021b). This is inherently related to the preservation of cultural heritage, including rediscovery of history of architecture and places that feel familiar, or places that are in harmony with the natural world. The same protection and care should be extended to unique places and forms that appeal to people's creativity and imagination (COM, 2021b).

Today, various models for the aesthetic quality of architecture and the built environment are identified. This is characterised by the coexistence of traditional architecture and new building styles, depending on the region, available technology, and climatic conditions. As a result, European modern and historical architecture is characterised by a desirable diversity that should be enhanced and protected. At the same time, we are witnessing and contributing to a paradigm shift in the creation of living spaces. The contemporary approach emphasises sustainable design, environmental protection, supporting local communities, and satisfying aesthetics. There is an increasing use of local, natural building materials, greater attention to the material and cultural surroundings, and a concern to perpetuate the heritage for future generations of Europeans. Human beings remain the focus of architects' and planners' attention, but modern science is creating new tools to assess their wellbeing, including aesthetics.

Built heritage should be enhanced or preserved and contemporary design should take into account the sense of place and the characteristics of natural and cultural heritage, open landscapes, sites and buildings, including their context. Context in relation to the New European Bauhaus refers to the built and non-built environment and landscape in terms of scale, typology and materiality, while sense of place encompasses the local character, unique identity and distinctiveness of a place and the attachment of people to that place (European Commission, 2021b). Beauty, context and sense of place are essential criteria for high-quality Baukultur within the Davos Baukultur Quality System. Importantly, places with high-quality Baukultur, well embedded in their built and natural context, encourage people's emotional response to the place by building a positive relationship with it. A crucial part of such context is an overall sensory experience, in which a sense of place is built with understanding of the relationship between objects, spaces and people, enhancing user satisfaction and quality of life (SFoC, 2021).

Assessing and improving beauty in an all-encompassing and integrated way within the built environment and place-making projects require taking into account all the characteristics, connections and phenomena of a geographically defined area in which a place – a single building or a larger unit such as an industrial area or a village – is embedded. In other words, the relation of a place to its surroundings is required at any scale over time. It is, thus, crucial that contemporary design activities consider the sensory perception of the place – visual, acoustic, tactile and olfactory impressions – and that the project solutions foster the creation of a strong sense of place and offer high performance landscapes and sites as places to live, work and recreate. This is expected to provide aesthetic enjoyment, encourage identification and familiarity, contributing to increase the attractiveness for residents and tourists, going beyond the artistic dimension to produce a positive impact on wellbeing of the inhabitants/users of buildings and spaces.

Beyond addressing the aesthetic, psychological and cultural needs of the people in their relationship with the surrounding built environment, setting functional and technical requirements is essential to ensure the high-quality and liveability of projects and spaces for everyone and for the long term. Thus, Beauty is further strongly concerned with two objectives connected to the quality of experience.

The first one seeks to enhance within the built environment the comfort, wellbeing, health and safety of users, regardless of age, ability or background, in normal operational conditions and in face of potential natural and man-made hazards. The built environment is exposed to various hazards that can cause extensive damage, resulting in substantial economic losses and, in extreme cases, loss of lives. Within this first objective, it is crucial to reduce the impact of such hazards by ensuring a comprehensive assessment of the risks and adopting adequate solutions to mitigate them, enhance preparedness and functionality retention, minimise the operation disruptions and allow a swift recovery process following the emergency. However, threats to users are not only posed by disasters. Significant background noise from external and internal sources of airborne, impact noise and noise from services, poor perceived thermal comfort, and inadequate quality and composition of natural and artificial lighting may compromise overall physical, mental and social wellbeing of the users. On the other hand, design solutions that integrate opportunities for physical movement to prevent sedentary behaviour or physical inactivity may improve user health and productivity. Finally, a further reduction of risk to people and enhancement of their wellbeing stem from a design that ensures the ease of use and operation for all, to the greatest extent possible, irrespective of their cognitive, physical, and sensory abilities.

The second objective aims to achieve high environmental performance through a circular use of construction products, beyond the expected service life, while integrating rigorous decision-making into the procurement and design processes. Within this objective, the integration of emerging and disruptive strategies and methods for data acquisition, automation, and digital information and analysis into the design and delivery activities is encouraged. Such integration may serve as a driver of enhanced quality of the products as well as increased safety of the actors involved in the construction and optimised allocation and consumption of resources. Furthermore, high-quality design, construction and management practices are promoted. This includes favouring more durable elements and components, adopting design solutions capable of accommodating changes in needs or market conditions and facilitating disassembly for reuse and recycling, to retain the highest utility and value of construction products over time. Responsible sourcing of construction products during procurement and efficient material use are integral to this objective. Such efforts are anticipated to reduce both mass and carbon embodied into buildings, mitigate consumption of resources and minimise waste production. Achieving these goals necessitates active involvement from all actors, namely design teams and contractors, with proven suitability to pursue professional activities, economic and financial standing, technical and professional ability as well as extensive experience with certification, design, construction and/or management of buildings and living spaces with improved environmental performance.

4.2 Assessment targets to achieve

To ensure that a high level of beauty is achieved eleven assessment targets are identified, each addressing key concerns in the evaluation process.

4.2.1 Integration of emerging technologies

Digital technologies have emerged as enablers of enhanced customer experience, quality, competitiveness, transparency, safety, resource efficiency and productivity (Baldini et al., 2019; ECSO, 2021). Therefore, their integration across key sectors of the economy is expected to actively contribute to sustainable development, by introducing novel production processes. In particular, the European Union has taken proactive steps towards the digital transformation of the construction sector. This sector is currently one of the least digitalised in the economy, characterised by a low adoption rate of innovative systems and methodologies. Furthermore, considerable variability in market maturity and technology readiness across different disciplines and stakeholders is present throughout the entire building lifecycle and supply chain (Papadonikolaki et al., 2022). Full scale digitalisation of the construction sector is expected to yield annual global savings up to 20% across diverse stages of the building lifecycle (Baldini et al., 2019). This digital transformation is expected to optimise production and generate new business models, replacing some existing jobs while creating new ones. This shift is fostered by manual labour automation, digitalisation of processes and coordination of tasks and activities (van der Heijden, 2023). A significant impact within the construction sector is also anticipated in terms of safety. Digital technologies have the potential to drastically enhance worker safety by reducing the likelihood of errors, supporting training initiatives and skills development, and minimising or replacing human involvement in heavy physical labour, operations in hazardous environments and repetitive tasks (Trask and Linderoth, 2023). To this end, the establishment of a secure environment that facilitates the safe interaction and coexistence of human operators and robots in construction sites is a key enabler (Baldini et al., 2019). Finally, the Smart Building, Infrastructure and City paradigm is leveraging digitalisation and big data revolution to enhance resilience and performance of built assets.

The commitment of Member State policymakers to digitalisation is evident through the implementation of active measures to foster this transformation. Support mechanisms include grants, loans and equity investments as well as the provision of technical assistance and platforms dedicated to skills development and knowledge transfer. Furthermore, the widespread adoption of e-services, for purposes ranging from data storage and sharing to streamlining administrative and bureaucratic procedures, plays a pivotal role in facilitating the digital transition (ECSO, 2021).

Three categories of emerging technologies for the Architectural Engineering and Construction (AEC) sector have been identified (Baldini et al., 2019; ECSO, 2021):

— Data acquisition: sensors, internet of things (IoT), 3D scanning.

— Automating processes: robotics, 3D printing, drones.

— Digital information and analysis: building information modelling (BIM), virtual/augmented reality (VR), artificial intelligence (AI), digital twins.

Some of the above technologies are more relevant for construction or operational phases of the building lifecycle, while the present self-assessment method focuses on promoting their integration into decision-making and processes at the design phase.

4.2.2 High-quality design and delivery

The organisation, qualification and experience of the actors involved in the design, construction operation, maintenance and deconstruction of a built asset significantly influence the quality of design and delivery and the final performance of projects. Therefore, the Public Procurement Directive (Directive, 2014) define a set of criteria for contract awarding that emphasises competences and expertise required of the involved parties. The use of these criteria should be expanded in procurement processes to enhance competitiveness and quality. The European Union has been actively promoting this transition by advocating for strategic plans for green and circular procurement, as well as introducing voluntary or mandatory criteria for selection. These initiatives aim to address a prevailing trend where more than 50% of the procurement procedures in the public sector adopt the lowest price as the award criterion (European Commission, 2017b). Green Public Procurement (GPP) extends beyond the Public Procurement Directive (PPD) criteria, specifically targeting goods, services and works with high environmental impact. GPP promotes the procurement of products that reduce this impact and minimise waste throughout their life cycle, compared to non-green alternatives with the same primary functions that may otherwise be selected (COM, 2008). Similarly, a circularity-driven approach to procurement shifts the focus from short-term needs to long-term consequences of each purchase (European Commission, 2017a). The positive impact of sustainable procurement transcends environmental benefits and encompasses social and economic dimensions (ISO, 2017c).

In this perspective, procurement serves as a catalyst for fostering responsible production and consumption patterns. Markets for environmentally friendly products and services can be created or expanded by raising awareness and driving demand for 'greener' goods. Green markets, in turn, are expected to incentivise innovative businesses and solutions, including smart and clean technologies. Therefore, the attention is not only directed towards the competencies of the involved parties but also towards the characteristics of the products (COM, 2008). Moreover, sustainable procurement aims to promote ethical behaviour across its supply chains, avoiding bias and prejudice in decision-making, providing equal opportunities, identifying and preventing violations of the rule of law, and respecting internationally recognised human rights (ISO, 2017c). To achieve this ethical behaviour in production, purchase and consumption, ensuring a transparent, legal and responsible material sourcing is essential. All organisations should be committed to continually improve their practices, avoiding complicity with wrongful acts and taking responsibility for the actions and decisions made.

Although the aforementioned criteria for green and circular procurement have been developed with a focus on public procurement, they can equally inform private procurement practices, since the principles of responsible production, consumption, and ethical sourcing are relevant and beneficial across both domains (COM, 2008).

Finally, transition to a more circular economy implies promoting sufficiency, thus preventing excessive and unnecessary material consumption. The quality of design can be assessed in terms of efficient use of materials aiming at doing more with fewer resources. Ensuring, by design, the long-term resource efficiency throughout the building life cycle is a primary goal highlighted by the Level(s) framework (Dodd et al., 2021a). BS 8895 series (BSI, 2013a, 2015a, 2019) outlines material-efficient processes, key tasks, team members and their responsibilities, outputs specific to each work stage, along with supporting guidance and tools. Examples of suitable design measures for material efficiency can include:

- Increasing the utilisation factor of structural members.
- Designing to standard material dimensions to reduce offcuts and waste on site.
- Removing redundant materials from the design.
- Using materials that can be recycled and/or reused at the end of their service life.
- Making use of recycled and/or reclaimed materials.
- Designing for deconstruction and material reuse.
- Using prefabricated elements where appropriate to reduce material waste.
- Consider using an 'exposed thermal mass' design strategy to reduce finishes.
- Avoiding overspecification of predicted loads.
- Using lightweight structural design strategies.
- Making use of bespoke structural elements to reduce overall material use.
- 'Rationalisation' of structural elements.
- Optimising the foundation design to reduce embodied environmental impact.

Some of these measures, such as recycling, reuse, use of standard components and offsite construction are evaluated within other assessment targets of the Beauty dimension (e.g. Sections 4.2.1, 4.2.6) as well as in the Sustainability dimension (e.g. Sections 3.2.6, 3.2.9). The remaining main aspects are addressed within the present target.

4.2.3 Resilience of the built environment

Since 2004, over 3.3 billion people worldwide have been either injured, killed or left homeless due to natural disasters (CRED, 2024). In the EU, from 1980 to 2020, natural hazards affected nearly 50 million people and caused on average an economic loss of EUR 12 billion per year (World Bank, 2021). Recent years have seen an increasing trend in the number of disasters, fuelled by increasing urbanisation and environmental degradation that results in higher exposure of people and assets to natural hazards. With climate change expected to bring more extreme weather events and sea level rise, the severity of natural hazards is projected to increase, and with it the potential for higher losses in future disaster events. Growing political instability, geopolitical tensions and diversification of hostile groups, result in the potential for increased terrorist threats (NIC, 2023). Several global policies and directives have been issued to support measures for reducing risk from natural and man-made disasters. The most important is the Sendai Framework (UNDRR, 2015) which was issued by the UN General Assembly following the 2015 Third UN World Conference on Disaster Risk Reduction (WCDRR). The Sendai framework presents a paradigm for understanding and managing systemic risk from natural, human-made, technological, environmental and biological hazards (UNDRR, 2015). It advocates that disaster risk reduction must be at the core of economic, social and environmental policy at all levels. It also recognises the link between disaster risk reduction and sustainability, highlighting that disasters can set back sustainable development goals as they undermine poverty eradication and magnify inequality (IRDR, 2014). The Sendai framework therefore calls for the substantial reduction of disaster risk and losses in lives, livelihoods and health, as well as in economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries. The framework recognises that the state authorities have the primary role to reduce disaster risk, though this responsibility should be shared with other stakeholders including regional authorities and the private sector (UNDRR, 2015).

Achieving resilience under extreme events involves effective prevention, mitigation, preparedness, response and recovery. In the construction sector, the focus has traditionally been on the adoption of modern building codes for hazard resistance. This is an important part of the mitigation component of resilience, but project design can contribute to disaster response and recovery also, through the provision of means of evacuation, access for emergency services, and the preservation of functionality. Moreover, for a project to be inclusive for its users, measures need to be taken towards enhancing preparedness through training and drills, and organisational steps can be taken to promote faster restoration of services.

4.2.4 Health and wellbeing

The target addresses the design of indoor environment to promote physical, social and mental health and wellbeing. Time spent indoors accounts for roughly 90% of daily life (Fitwel, 2020). The quality, amenities and design of indoor environments are strongly linked to individual health outcomes and productivity.

According to the Environmental noise guidelines for the European region (WHO, 2018), environmental noise features among the top environmental hazards to physical and mental health and wellbeing, with a substantial associated burden of disease in Europe (WHO, 2011; Hänninen et al., 2014). In many cities across the EU, over 50% of the population (approximately 200 million people) are exposed to road noise levels above 55 dB day-evening-night level (L_{den}), which is above the recommended values by WHO (Kantor et al., 2021). Railway and aircraft noise affect a lower proportion of the EU population (approximately 50 million people), but both are significant sources of local noise pollution. Under the European Green Deal (COM, 2019), the EU has committed to achieve a zero-pollution ambition for a toxic-free environment. The 2021 zero pollution action plan 5 sets a specific target of reducing the number of people chronically disturbed by transport noise by 30% in 2030 as compared to 2017 (Directive, 2002). It is therefore widely recognised that providing a healthy acoustic environment is important.

External noise transmission into indoor areas is not the only source of noise discomfort. Indoor sources of noise also need to be considered in design. Most commonly, target indoor background noise levels and reverberation times are key metrics used to provide an appropriate acoustic environment within an enclosed space. Background noise (or ambient noise) must be calculated from external and internal sources of airborne, impact noise and noise from services (e.g. HVAC), considering the absorptive and reflective characteristics of façades, structural components and partitions. Reverberation times, indicate the suitability of sound transmission and speech intelligibility. They depend on the frequency of the noise as well as the absorptive properties of surfaces and fitting materials. The target values of these and other parameters adopted to define acoustic environments, vary with the use of the space, its type and level of occupancy, and with the needs of people using the space.

The quality and composition of lighting directly affects people's ability to conduct tasks within a space. Moreover, lighting has also been shown to affect mental wellbeing and physical health. This is because humans' circadian rhythm is linked to the natural day-night cycle, and the body requires periods of both light and darkness. Light exposure can affect people's moods, symptoms of depression, and rates of healing (WELL v2, IWBI, 2020). Appropriate illumination and visual contrasts also contribute to the information needed for wayfinding and for safety (IWBI, 2020). It is therefore important to design and implement a holistic lighting strategy that combines natural and artificial lighting to provide visual acuity, comfort, physical and mental health, and contributes to wayfinding and safety. Such a strategy must account for the diverse needs of occupants of different ages and abilities.

Thermal comfort is defined as "*the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation*" (ASHRAE, 2023). Thermal discomfort strongly influences user wellbeing and productivity as it affects alertness, moods, motivation and focus (Lamb and Kwok, 2016). Thermal comfort is subjective with gender, age, and climatic conditions, all affecting perceived thermal comfort (Nicol and Humphreys, 2002). The location and typology of the building along with outdoor climate and season also influence thermal comfort of occupants (Frontczak and Wargocki, 2011). Since a unique design for thermal environment will not suit all people, designers should aim for a thermal performance of projects that is comfortable for as many people as possible (IWBI, 2020). Devices for regulating thermal comfort can help adjust the environment to individual needs. Thermal comfort is important throughout the year, hence, as a rule, both heating and cooling must be considered.

A large proportion of the EU housing stock cannot provide adequate levels of thermal comfort because of a combination of a lack of insulation, poor quality windows, cold bridging through the building fabric, high levels of air infiltration and inadequate or poorly maintained heating systems (Dodd et al., 2021e). Attempts to provide better thermal comfort can result in large energy consumption in heating and cooling. Thermal comfort is also linked to indoor air quality as both are strongly influenced by the HVAC system used. It is important that design for thermal comfort is considered together with design for better indoor air quality and lower energy consumption (see Sections 3.2.1, 3.2.2 and 3.2.5 in Sustainability).

In 2022, globally, 7.2% and 7.6% of all-cause and cardiovascular disease deaths, respectively, were attributable to physical inactivity, with the proportions of non-communicable diseases (e.g. hypertension, dementia) due to physical inactivity equal to 1.6% and 8.1%, respectively (Katzmarzyk et al., 2022). Despite wide knowledge of the health benefits of regular exercise, over a quarter of the adult population do not meet the current public health guidelines for physical activity (Guthold et al., 2018). Modern desk-based learning and working environments also promote sedentary behaviour. Sedentary behaviour is different from physical inactivity and is characterised as very low-intensity, low-effort activities, such as sitting, and has distinct health outcomes, including higher incidences of obesity, cardiovascular risks and premature mortality (Saunders et al., 2020). A recent study (Santos et al., 2023) evaluated that 500 million new cases of preventable non-communicable diseases would occur globally by 2030 if the prevalence of physical inactivity does not change, with direct health-care costs of EUR 480 billion. This is preventable, and it is critical that future projects promote more active living by integrating opportunities for physical movement into their designs. Several recommendations exist along these lines, such as the Active Design guidance (Sport England, 2023; Sport England and BREEAM, 2019), and the WELL Movement concept (IWBI, 2020).

4.2.5 Accessibility

Accessibility is a fundamental human right (United Nations, 2007), and is defined in the context of the built environment as "*adjusting every detail of the built space to (accommodate) a large and varied group of potential users, with a focus on details of importance in relation to cognitive, physical and sensory abilities*" (Andersson and Skehan, 2016). 87 million people with disabilities are reported to live in the EU (European Commission, 2021a). According to the World Health Organization, around 16% of the world's population has a disability, which equates to over 1.3 billion people worldwide (WHO, 2023). In March 2021, the European Commission adopted the 'Strategy for the rights of persons with disabilities 2021-2030' (European Commission, 2021a), which builds on a previous strategy (COM, 2010) and aims to improve the lives of persons with disabilities in Europe and around the world. The provision of dignified and non-discriminatory accessibility is a part of this strategy. It should be noted that 'disabilities' are considered as comprising long-term physical, mental, intellectual or sensory impairments, which are often invisible (in line with Article 1 of United Nations, 2007). Included in physical impairments are reduced physical strength, dexterity and mobility that are associated with ageing. Population ageing is a demographic trend that has been apparent for several decades in Europe, with the number of people aged 65 and over projected to increase from the 2019 value of 90 million to 130 million by 2050 (Eurostat, 2020). This process is driven by low fertility rates and increasing life expectancy, which has significant implications for society and the economy.

Making the built environment accessible is widely recognised as having a significant social benefit. However, other benefits co-exist. Firstly, consideration of the specific needs and requirements of users allows the identification and mitigation of hazards and risks, thus contributing to user safety (European Committee for Standardisation, CEN, 2021b). Secondly, significant economic benefits have been highlighted in the literature (Terashima and Clark, 2021). Accessible design can improve access to information and communication, improve efficiency, and reduce barriers to employment and career advancement, ultimately increasing productivity of people in society. Moreover, developers and building owners will benefit from user satisfaction and increased productivity, resulting in higher visitor rates, social branding opportunities, broadening markets, and lower renovation and operation costs (Steinfeld and Smith, 2012).

Achieving accessibility of the built environment requires consideration of a wide set of human abilities and characteristics, which may be conflicting at times. Achieving accessibility for all is therefore not simple. Several design movements have put forward approaches for accessible design. Amongst these, Universal Design is widely acknowledged and involves the design of products, environments, programmes and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialised design (Centre for Excellence in Universal Design, 1997). The Universal Design approach is based on seven principles: simple and intuitive use; flexibility in use; size and space for approach and use; perceptible information; low physical effort; tolerance for error; equitable use. These concepts run through the EN 17210 performance standard (CEN, 2021b), which was developed to aid implementation of the UN Convention on the Rights of Persons with

Disabilities (United Nations, 2007) in Europe (COM, 2010). This performance standard and the associated technical report (CEN, 2021c) are described in Section 4.7, and are used in Section 4.8 as key references.

It would be beneficial to all projects to consider universal design principles in every design element, with consideration of its intended use and contribution to the project accessibility and functionality. In the context of the NEB self-assessment method, the design elements considered most important are those that contribute to ease of circulation, safe and intuitive wayfinding, and ease of use and operation of all amenities within the project boundaries.

4.2.6 Service life

Service life maximisation aims to ensure that buildings and products are designed to retain their utility and value over time. The current economy is dominated by a linear take-make-use-dispose principle, in which half of total greenhouse gas (GHG) emissions and most than 90% of biodiversity loss and water stress come from resource extraction and processing (COM, 2020). In particular, the construction sector generates over 35% of total waste in the EU, is responsible for about 50% of all extracted materials, and produces GHG emissions equal to 5-12% of total national emissions (COM, 2020). Most of the environmental impacts relate to the production and construction of structures and façades (Dodd et al., 2021c). As an alternative, circular economy has gained much attention. Circularity pursues a restorative and regenerative model that reduces single-use and premature obsolescence, decoupling economic growth and resource consumption and fostering the implementation of sustainable development goals (Ellen MacArthur Foundation, 2015; Murray et al., 2017; Schroeder et al., 2019; Dokter et al., 2021). The European Commission has proposed a Circular Economy Action Plan, as one of the main building blocks of the European Green Deal, to foster this systematic shift towards a climate-neutral, resource-efficient and competitive economy (COM, 2020). Responding to it, many EU Member States have adopted proactive implementation strategies.

A main goal of circular economy is to guarantee that products retain their highest utility, as well as their embedded environmental and economic value, over time (Ellen MacArthur Foundation, 2015; Webster, 2015; Nußholz, 2017; Reike et al., 2018; COM, 2020). Circular economy involves ensuring durability, maintainability, and repairability of products, maximising the value of the resources invested in their production. However, to ensure that such long-lasting products are not disposed before the end of their service life, designing buildings that are more easily adapted and upgraded to suit uncertain and fast-evolving future scenarios is essential. Flexible and adaptable systems can accommodate to changing household, personal and business circumstances, variations in the overall demand or conversions in the use. Design for adaptability and renovation does not simply address the capability of load bearing elements to sustain increased actions due to change in use or height and mass of the building. It also aims at facilitating future modification of the layout, and repurposing of internal spaces. Service and equipment distribution and their ease of replacement are additional critical aspects, as they typically pose a major barrier to change in use or changes in fuel or input energy sources (Dodd et al., 2021c).

Although adaptability may be more compelling for non-residential buildings, in residential buildings specific drivers of adaptability, like starting a family, ageing and changes in circumstances that lead to reduced mobility, alternative requirements for living spaces with different cultures upon changing tenure, as well as the need for suitable home working environments should be properly addressed (Dodd et al., 2021c). Some requirements for adaptability may be fulfilled by universal design principles (ISO, 2020), which are evaluated within the accessibility assessment target of the Beauty dimension (Section 4.2.5).

Circularity is further promoted by design for disassembly, deconstruction and reuse. Deconstruction principles and good practices comprise (ISO, 2020) independence, avoidance of unnecessary treatments and finishes, simplicity and standardisation. The ease of access to materials, components or connectors of an assembly, and the possibility of disassembling without the use of specialised equipment, causing negligible or no damage, is essential to prevent unnecessary waste during deconstruction. Leaving connections exposed, visible and accessible, with necessary room on all sides to operate them, is a way of promoting ease of disassembly for reuse. Moreover, elements with a minimum number and type of components, parts and materials are in general easier to handle and disassemble, reducing the necessary tools and techniques. Similarly, standardisation ensures that well-established and repetitive techniques can be used for the deconstruction and increases the likelihood of a larger demand for reuse (ISO, 2020; Dodd et al., 2021d).

Additionally, the circular economy model favours the use of renewable resources, the minimisation of hazardous materials and the integration of higher proportions of recycled and recovered content. Other targets within the present self-assessment method are concerned with these circular economy-related measures, namely Section 3.2.9 in Sustainability.

It has been estimated that decisions made at the design phase determine more than 80% of the environmental impact of products (COM, 2020). Therefore, promoting design practices that extend the service life of buildings, components, parts or materials, and foster reuse is an essential step of the paradigm shift towards the circularity model. This effort is expected to reduce embodied life cycle impacts and resource consumption, extending the functional use that can be obtained from the initial investment of resources (Dodd et al., 2021c, d).

4.2.7 High-level aesthetic acceptance

The experience of architecture and space by observers and users is possible thanks to the human sensory system. Although human perception is multisensory in nature, the dominant sense is vision, which means that people tend to perceive their surroundings primarily through images. Studies show that between one third and more than half of the cerebral cortex is involved in the processing of visual information, 12% in the processing of tactile information, about 3% in the processing of auditory information, and less than 1% is responsible for the processing of olfactory and gustatory information (Eberhard, 2007). Nevertheless, there is a growing awareness of the interconnectedness between the senses and their influence on how we perceive the built environment.

To achieve a high level of aesthetics in the built environment, the creation of buildings and spaces with desirable visual qualities and a positive impact on the sensory and cognitive user experience should be reinforced. Visual qualities are based on universal values identified by interdisciplinary architecture research and widely accepted realisation practices. Formal qualities include order, contrast, transparency and novelty, and their appropriate compilation has a positive impact on visual richness. Beauty is also associated with pleasant sensory experiences for users that go beyond a sense of comfort, defined by interior temperature, light intensity, ergonomics, and basic functionality, as assessed by the target of health and wellbeing (Section 4.2.4). Research on human sensory perception describes the process of interaction between the environment and the observer through cognitive, emotional as well as physiological responses influencing spatial behaviour. We have become accustomed to giving priority to visual judgements and perception in evaluations of the built environment, somehow building up its superiority over auditory, olfactory, or tactile impressions. However, it has been proven that there is a close relationship between multisensory architectural and spatial experiences and the wider wellbeing of users has been identified (Spence, 2020). Aesthetic experience is concerned with combining feelings of pleasure and satisfaction in a coherent and complete way, and it is intended to engage with all senses through a variety of architectural means. Material and technological innovations can enrich the sensory experience and provide interactive and engaging stimulation, but do not determine the overall value of the aesthetic experience of architecture (Mallgrave, 2018). The intellectual and emotional factor of the perception of spaces and buildings is not less important. The cognitive aspects enrich the aesthetic experience and thus support a beautiful built environment.

4.2.8 Spatial coherence in planning and design

The concept of coherence is based on a spatial quality that results from the complex interactions among various elements within an urban structure. Urban space quality relies on morphological interactions, with strong connections at lower scales forming module-like units such as streets and blocks. These lower-level modules connect with higher-level ones to form a coherent space within a larger context (Salingaros, 2000). Spatial coherence in urban design is central to the design of successful and vibrant cities. Integrating spatial interventions into the urban pattern while preserving local identity improves the overall quality of the urban fabric, contributing to a sense of place and fostering a lasting connection between people and their environment. It is also of great importance that the designed interventions address challenges and opportunities in a way that considers the interconnectedness and interdependence of regions and localities. Efforts in this direction are important for the promotion of a more balanced and sustainable territorial development (Rodríguez-Pose, 2018).

4.2.9 Preservation of natural and cultural heritage

Heritage embodies the accumulated creative achievements of the past, and its preservation represents a responsibility of contemporary society. The recognition and maintenance of heritage should be integral to any development strategy, ensuring its relevance for future generations amidst the ongoing changes of the present. Given the emotional connection between people and their environment, a sense of place is an important factor in motivating people to act on behalf of their heritage and context (SFoC, 2021). However, achieving a high level of aesthetics in the built environment does not just mean protecting built heritage, but also integrating its substance and values in planning and building. Ensuring a high-quality urban environment is essential for the cultural vitality, economic development, and social welfare of cities and regions (UNESCO, 2005).

The landscape plays an important role in enhancing the quality of life and contributes to the cultural heritage of regions. It is a product of the interaction of natural and human factors, shaping local cultures and contributing to the European identity (Council of Europe, 2005). Historic urban landscapes, as representations of landscapes in historic areas, carry traces of current and past social expressions. These areas, including their surroundings, should be seen coherently, with a specific character deriving from the interaction of their parts. Contemporary architecture, when integrated into historic environments, should encompass planned interventions such as new buildings, extensions, and conversions, all contributing to the management of the historic urban landscape.

4.2.10 *Genius loci* and sense of belonging

The sense of belonging, a cultural motivation that drives human collaboration in creative efforts, is closely tied to the establishment and development of settlements in specific places that have profound meaning and significance. This connection extends beyond communities to encompass monuments, works of art, and historical cities. Significance, as an intangible quality that is sustained by material resources and environmental context, indicates the importance of recognising and preserving heritage. *Genius loci* emphasises that new developments must respect the existing urban fabric and preserve its qualities and characteristics, so that the place remains recognised for its heritage value over generations. The aim is to maintain the spirit or essence of a place, by recognising and preserving its characteristic features, emotional identity (elements with deeper meanings and emotional connections for its inhabitants), and other aspects within a natural or constructed environment (Norberg-Schulz, 1980; Garnham, 1985; Jackson, 1994). Hereby environment pertains to the ambiance shaped by human activities within a structure and its surrounding natural landscape. Work on a specific space should commence with a thorough examination and consideration of the unique spirit that characterises that place. By employing a sensitive adaptation process (Fusco Girard and Vecco, 2019), the *genius loci* of an existing building and place can be safeguarded.

4.2.11 Aesthetic perception of buildings and spaces

The target addresses the understanding of aesthetic perception of buildings and spaces through comparison to actual styles and tendencies. In architecture, the concept of style is widely used as a typological tool, the result of critical reflection focused on establishing similarities between buildings. In this context, it provides a useful indicator of coherence in the built environment. It is worth recalling, however, that contemporary architectural practices and theories react vividly to changing economic, social and political conditions and are both global and local disciplines. Their susceptibility to change, as well as the lack of universally recognised aesthetic canons and rules, makes it difficult to propose a unique stylistic and formal typology of trends present in contemporary architecture. Regardless of the style, it is possible to identify certain characteristics of a building/space such as unity, order, contrast, transparency and novelty that provide users with a positive visual and aesthetic experience. The arbitrary support of a chosen style can be seen as exclusionary (Hopkins, 2014). Therefore, existing building assessment standards do not use references to any particular style, but one can find references to the idea of biophilic design. The WELL v2 Building Standard (IWBI, 2020) uses biophilic design as a qualitative and quantitative metric. The qualitative metric must incorporate nature, natural patterns, and nature interaction within and outside of the building. For the quantitative portion, projects must have outdoor and indoor biophilia, as well as water features. The Living Building Challenge standard identifies the need to seek solutions in architectural design to intentionally incorporate nature into the fabric of buildings through environmental features, light, natural shapes and forms (MHCLG, 2020).

4.3 Selection criteria and list of KPIs

The NEB dimension of Beauty is strongly multidisciplinary and encompasses various and multifaceted approaches to achieve the set targets (Section 4.2) and to analyse the main aesthetic and quality of experience values. Hence, the first phase of the development of the method has involved identifying the most important areas of the Beauty dimension. The focus areas have been mapped selecting key definitions to establish a conceptual framework, along with guiding questions, formulated to define relevant aspects to be rated and assessed.

In addressing these questions, a thorough review of existing policies, standards, guidelines, codes and well-established rating frameworks has been undertaken, leading to the identification of a comprehensive set of criteria and thresholds. Defining clear and measurable criteria to objectively assess aesthetic requirements has proven particularly challenging. Indicators and thresholds have been carefully selected to surpass national regulatory standards, aiming for best practices within the defined targets. This process initially yielded numerous potential indicators, which were subsequently rationalised, harmonised and condensed into a more manageable set by resolving duplications, interlinkages and overlaps among candidate indicators, including those from other NEB dimensions. The identification of these indicators has represented a pivotal step within the procedural framework. This set underwent testing on different case studies encompassing varying scales, contexts and project types. The results of these tests informed a second selection of indicators, which focused on their relevance, applicability and effectiveness.

This second stage has led to the final development of key performance indicators (KPIs), each one comprehensively evaluating a specific assessment target by combining interlinked indicators and metrics. The selection or exclusion of indicators was guided by their readiness and maturity, as well as their alignment with the NEB ambitions (European Commission, 2022). To this end, indicators were categorised as currently established and used within academia and industry, emerging indicators expected to be used in the near future, or novel ones which require more research to be regularly applied in the far future. Moreover, the ambitions of the NEB dimension of Beauty have been duly considered, namely to (*i*) (re)activate the qualities of a given context while contributing to physical and mental wellbeing, (*ii*) connect different places and people and foster a sense of belonging through meaningful collective experiences, and (*iii*) integrate new enduring cultural and social values through creation (European Commission, 2022). The final set of indicators underwent meticulous review and validation. The entire process has reflected a commitment to evidence-based development, ensuring that the developed KPIs are relevant, accepted, credible, easy to use, and robust, providing a structured framework for evaluating aesthetic and quality of experience aspects across diverse scenarios.

As a result of this process, the following **key performance indicators** have been developed for self-assessment within the Beauty (B) dimension:

B.1 Digitalisation in construction: the extent to which disruptive technologies are adopted, with a specific focus on the establishment of a collaborative working environment and the integration of digital technologies, premanufacturing and automation.

B.2 Quality of design and delivery: the extent to which high environmental performance and project quality are ensured through the engagement of actors with relevant experience and competencies, the responsible procurement of certified products, and the optimisation of the quantity of sourced materials.

B.3 Improving building resilience to extreme events: the extent to which the design considers the different natural and man-made hazards to which the project may be exposed, including the effects of climate change, ensuring that the building and its components are designed to resist them and that preparedness measures are taken to foster more effective emergency management and rapid restoration of project functionality post-disaster.

B.4 Ensuring occupant health, comfort and wellbeing: the extent to which the project design provides a healthy environment with adequate visual, thermal and acoustic comfort, supporting and promoting physical, social and mental health, and in which the users can easily cater to their needs, have a meaningful experience and thrive.

B.5 Improving accessibility of the built environment for everyone: the extent to which the project space is adjusted to a large and varied group of potential users regardless of their ability or background, enabling non-discriminatory accessibility and movement through, around and between spaces, conveying spatial information to support the identification and comprehension of the environment and presenting easily usable and operable elements.

B.6 Maximising durability and service life: the extent to which the service life of building elements and components is maximised through the selection of durable products, the implementation of design considerations that accommodate substantial changes in user requirements and needs, and the promotion of ease of disassembly, reuse and recycling.

B.7 Ensuring high level of aesthetic acceptance of buildings and spaces: the extent to which the design solutions support and promote a positive sensory experience, both visual and non-visual, allowing acceptance of architecture and space and leading to support for the social, cognitive and emotional development of users.

B.8 Providing spatial coherence in planning and design: the extent to which the project fits into its context, integrating the spatial transformation into its built and non-built environment, creating harmony, unity, and order, preserving, reusing or adapting existing spaces, including open ones, and ensuring compatibility with the surrounding setting.

B.9 Improving preservation of cultural and natural heritage: the extent to which cultural and natural heritage within the context of projects, including traditional cultivated landscapes and original, historic urban green areas, are protected and preserved for the benefit of present and future generations, maintaining their authentic character and visual integrity by adopting solutions that are aligned with best conservation principles, respectful of the heritage value and minimally invasive.

B.10 Maintaining genius loci and improving sense of belonging: the extent to which the emotional bond and attachment among community members is nurtured and the unique spirit of the place is identified and preserved, encompassing its characteristic features, the authenticity of the built and non-built environment, as well as all associated interactions and sense of identity, within the context of projects.

B.11 Understanding aesthetic perception of buildings and spaces through comparison to actual styles and tendencies in art and architecture: the extent to which the project including buildings and spaces presents clear distinctive features that allow categorisation according to specific styles and tendencies, based on their common linguistic form and cultural context, and features that provide users with a positive visual and aesthetic experience.

The KPIs together with the associated indicators and indicator weights ($w_{B.i,j}$) are provided in Table 48. The same table presents also the field of application and consideration of indicators according to the project classification based on scale, type, main use and relevance to cultural heritage.

Additional information on each KPI is provided in Sections 4.4–4.14, including the rationale, background, calculation method, main actors involved, and input data needed for the evaluation. The calculation method addresses the evaluation of indicator scores, KPI scores and KPI performances classes according to Sections 2.2.1 and 2.2.2.

Table 48. Key performance indicators (KPIs) within Beauty.

KPI[1]	**Indicator**	**Scale**	**Type**[2]	**Main use**	**Cultural heritage**[3]	**Weight ($w_{B.i,j}$)**
Digitalisation in construction (B.1)	Collaboration and information sharing (B.1.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.5
	Premanufacturing and automation (B.1.2)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.5
Quality of design and delivery (B.2)	Competencies of design team and contractors (B.2.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
	Responsible material sourcing (B.2.2)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
	Compliance with material efficiency opportunities (B.2.3)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation[5]	Residential/ Non-residential	Not affected	0.4
Improving building resilience to extreme events (B.3)	Hazard characterisation (B.3.1)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.35
	Hazard resilient design (B.3.2)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.35
	Consequence mitigation (B.3.3)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
Ensuring occupant health, comfort and wellbeing (B.4)	Indoor acoustic environment (B.4.1)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.25
	Lighting environment (B.4.2)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.25

	Thermal comfort (B.4.3)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.25
	Promotion of physical movement (B.4.4)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.25
Improving accessibility of the built environment for everyone (B.5)	Ease of circulation (B.5.1)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.33
	Safe wayfinding (B.5.2)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.33
	Usability and operation (B.5.3)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.34
Maximising durability and service life (B.6)	Durability (B.6.1)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
	Design for adaptability (B.6.2)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.4
	Design for deconstruction (B.6.3)	Building/ Neighbourhood[4]/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
Ensuring high level of aesthetic acceptance of buildings and spaces (B.7)	Visual experience of architecture and space (B.7.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.6
	Multisensory experience of architecture and space (B.7.2)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.4
Providing spatial coherence in planning and design (B.8)	Spatial coherence and urban cohesion (B.8.1)	Building/ Neighbourhood	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.4
	Re-use of spaces and buildings (B.8.2)	Building/ Neighbourhood/ Urban	Newbuild[5]/ Renovation	Residential/ Non-residential	Not affected	0.3
	Green urban areas (B.8.3)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
Improving preservation of cultural and natural heritage (B.9)[6]	Historical fabric preservation (B.9.1)	Building/ Neighbourhood	Renovation	Residential/ Non-residential	Yes[5] (statutory protection)	0.6
	Integrated heritage landscape conservation (B.9.2)	Building/ Neighbourhood	Renovation	Residential/ Non-residential	Yes[5] (statutory protection)	0.4
	Improving preservation of cultural and natural heritage in renovated buildings (B.9.3)	Building/ Neighbourhood	Renovation	Residential/ Non-residential	Yes[5] (with cultural value, but without statutory protection)	1
Maintaining *genius loci* and improving sense of belonging (B.10)	Sense of place harmony (B.10.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Non-residential	Not affected	1
Understanding aesthetic perception of buildings and spaces through comparison to actual styles and	Cognitive experience (B.11.1)	Building	Newbuild	Residential/ Non-residential	No	1

tendencies in art and architecture (B.11)						

[1] Although minimum KPI scores are not prescribed in the NEB self-assessment method, it is highly recommended that all KPIs reach the Acceptable performance class.
[2] In the case of renovation projects, the evaluation of KPIs B.1, B.2, B.3, B.4, B.5 and B.6 overall focuses on the specific aspects of buildings and spaces that are affected by the proposed intervention works. However, when indicators and/or metrics address aspects that are not altered by the renovation works, their evaluation should consider the as-built state (i.e. condition before the intervention is set).
[3] Yes: Indicator applicable only to cultural heritage; No: Indicator non-applicable to cultural heritage; Not affected: Indicator applicable irrespective of cultural heritage.
[4] The assessment should focus on representative building attributes within the neighbourhood or urban scale project. The user may assess a building that can represent on average the different attributes (or integrates the most dominant ones) within the project. Alternatively, the user may perform multiple assessments corresponding to distinct building designs representative of the building stock. In the latter case, the indicator score is estimated as a weighted average, with the weights obtained from the relative occurrence of each building design (in terms of number of buildings, built area, or other features).
[5] Additional conditions apply.
[6] In the case of B.9, users must decide utilising either indicators B.9.1 and B.9.2, or indicator B.9.3, based on whether cultural heritage buildings/spaces are legally protected or not.

Source: JRC.

The **KPI performance class scores** (PCS) assigned to all KPIs of the Beauty dimension, as a function of the attained KPI performance class and KPI score (Section 2.2.3), are provided in Figure 46.

Figure 46. KPI performance class scores (PCS) in the Beauty dimension.

Performance class:	Low	Acceptable	Good	Excellent
KPI performance class score (PCS):	0	40	70	100

Source: JRC.

The Beauty **dimension score** (B) (Section 2.2.4) is evaluated according to Equation (146). The number of the considered KPIs (*m*) within the equation depends on the project classification according to scale, type and main use (reported in Table 48).

$$B = \sum_{i=1}^{m} (w_{B.i} \cdot PCS_{B.i}) \Big/ \sum_{i=1}^{m} (w_{B.i}) \quad (146)$$

A variable weight ($w_{B.i}$), as reported in Table 49, is assigned to indicators, selectively modifying the weight provided in Equation (147).

$$w_{B.i} = 1/m \quad (147)$$

Table 49. Beauty key performance indicator weights.

Key performance indicator (KPI)	**Weight ($w_{B.i}$)**
Digitalisation in construction (B.1)	1 / m
Quality of design and delivery (B.2)	1 / m
Improving building resilience to extreme events (B.3)	1 / m
Ensuring occupant health, comfort and wellbeing (B.4)	1 / m
Improving accessibility of the built environment for everyone (B.5)	1 / m
Maximising durability and service life (B.6)	1 / m
Ensuring high level of aesthetic acceptance of buildings and spaces (B.7)	(1 / m) · 1.5
Providing spatial coherence in planning and design (B.8)	(1 / m) · 1.25
Improving preservation of cultural and natural heritage (B.9)	1 / m
Maintaining genius loci and improving sense of belonging (B.10)	(1 / m) · 0.25
Understanding aesthetic perception of buildings and spaces through comparison to actual styles and tendencies in art and architecture (B.11)	1 / m

Source: JRC.

The Beauty **dimension performance class** is assessed considering the dimension score and dimension thresholds according to Figure 47.

Figure 47. Beauty performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
Beauty dimension thresholds (t_B):	$0 \leq$	$t_{B, Acceptable} \geq 40$	$t_{B, Good} \geq 65$	$t_{B, Excellent} \geq 85$	≤ 100

Source: JRC.

Most indicators and thus KPIs in the Beauty dimension are designed to be implemented at all project spatial scales, types and main uses (Table 48). Notable exceptions concern B.9 KPI that refers to cultural heritage so the KPI is designed to be implemented only for renovation project type and cannot be implemented at urban scale, B.10 KPI that can be applied only to projects with non-residential use, and B.11 KPI that can be implemented only at building scale and for newbuild project type.

The evaluation of several indicators and/or metrics is affected by the project classification in terms of both project scale and type. When a project, classified into the neighbourhood or urban scale, involves several buildings with distinct design characteristics, thus likely leading to different indicator scores for each of them, the evaluation of the relevant indicator shall be carried out by identifying representative samples of buildings with similar design features. For each of them, a separate assessment shall be conducted. The overall average indicator score characterising the neighbourhood/urban-scale project is provided by weighting the evaluation of each specific typology by its relevance (e.g., number of occurrences) within the whole project. In the case of renovation projects, the assessment focuses on the specific aspects of buildings and spaces that are affected by the proposed intervention works. However, when indicators and/or metrics address aspects that are not altered by the renovation, their evaluation should consider the as-built state (i.e. condition before the intervention is set).

On a few occasions, apart from the project classification (scale, type, use), some additional conditions apply for the implementation of an indicator. For example, B.2.3 is applicable when new floor systems are constructed either in newbuild or renovation projects (e.g. as part of the interventions works). Accordingly, the indicator is omitted in renovation projects that do not intervene in the floor system. When a renovation project, classified into the neighbourhood or urban scale, includes buildings with modified floor systems and buildings without such modifications, the two cases must be assessed separately, as two distinct projects. This is the same approach as the one followed when a neighbourhood/urban scale project includes both types (newbuild, renovation) and/or uses (residential, non-residential) (Section 2.3.2). In all these cases the project should be assessed as multiple ones addressing separately the different classes (e.g. newbuild and residential; newbuild and non-residential; renovation and residential; renovation and non-residential) at the scale of the complete project. Another example refers to B.8.2 indicator that is applicable at building scale to a newbuild project exclusively when the new building is planned on a brownfield site. Accordingly, the indicator is omitted in newbuild projects that refer to a new building designed on a greenfield site. Similarly, at neighbourhood and urban scale, B.8.2 is applicable to newbuild projects when the new neighbourhood or urban project involves a brownfied site, or at least some areas of it (beyond areas of a potential greenfield site).

Context influences B.3 regarding the definition of the hazards expected to affect the buildings. Specifically, the assessment is governed by the combination of hazard characterisation and hazard resistant design which has the most significant negative impact on performance. Context further affects the renovation of heritage buildings in B.9, for which alternative formulations are provided depending on whether statutory protection is enforced or not.

4.4 Digitalisation in construction (B.1)

4.4.1 Description and assessment

Under *Digitalisation in construction KPI (B.1)* the following indicators are assessed:

— *Collaboration and information sharing (B.1.1)*: the extent to which the adopted information management processes establish a collaborative working environment and foster the integration of digital technologies.

— *Premanufacturing and automation (B.1.2)*: the extent to which construction adopts premanufacturing and preassembly processes, and pursues automation.

B.1 score is evaluated as follows:

$$B.1 = \sum_{j=1}^{2}\left(w_{B.1.j} \cdot B.1.j\right) \Big/ \sum_{j=1}^{2}\left(w_{B.1.j}\right) = 0.5 \cdot B.1.1 + 0.5 \cdot B.1.2 \leq 100 \qquad (148)$$

The first indicator (B.1.1) measures the level of digitalisation and coordination among all stakeholders from conceptual design phases to construction, operation, and deconstruction. B.1.1 is strongly related to the implementation of BIM practices. BIM is likely the most used digital technology in the construction sector. Its consistent application is expected to produce positive returns on investment, with reduction of overall projects costs and significant optimisation of time, resources allocation and waste production (ECSO, 2021). Moreover, BIM solutions play an important role in facilitating the integration of additional disruptive technologies and methodologies. These include VR/AR, data-model integration and IoT, digital twinning, parametric and generative design as well as other AI-assisted tasks, across the lifecycle of the building. These methods can help architects, engineers, and construction professionals to significantly streamline the design process and reduce resource consumption (Fonseca Arenas and Shafique, 2023; Guignone et al., 2023). Therefore, the integration of these methods within the design and management processes is positively evaluated.

The second indicator (B.1.2) places emphasis on advancing automation, fostering materials innovation and promoting efficiencies from off-site, near-site, and on-site premanufacturing and preassembly. These initiatives are anticipated to drive greater efficiency and yield more consistent, defect-free outcomes by standardising products as well as prioritising repeatable, digitally aligned, manufacturing-oriented methods over labour-focused approaches. However, the indicator does not aim to exclude traditional craft-based methods which constitute an important legacy of European cultural and constructive tradition and may add intrinsic value to the building. The proposed metric serves as a proxy for evaluating the extent of integration into the project of technologies collected under the term of Modern Methods of Construction (MMC), as defined within the framework established by the UK Ministry of Housing, Communities & Local Government (MHCLG, 2019).

Figure 48 provides B.1 KPI thresholds adopted in the self-assessment method.

Figure 48. B.1 performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.1 thresholds ($t_{B.1}$):	0 ≤		$t_{B.1, Acceptable}$ ≥ 40		$t_{B.1, Good}$ ≥ 60		$t_{B.1, Excellent}$ ≥ 80		≤ 100

Source: JRC.

The KPI and its two indicators are designed to be implemented at all project scales, types and main uses (Table 48). The assessment of B.1.1 requires the identification of the main methods and technologies integrated within the project, therefore, it is not affected by the project classification (i.e. scale, type main use).

In the case of B.1.2, the evaluation is conducted through estimation of the costs for the complete Bill of Quantities (BoQ) and Materials (BoM) (Donatello et al., 2021) including manufacturing, logistic, transportation, site labour and preliminaries. To make and manage a harmonised estimate and classification of BoQ and BoM during the design stage, the Level(s) inventory template (Donatello et al., 2021) may be adopted. B.1.2 evaluation is affected by the project scale and type.

When a project, classified into the neighbourhood or urban scale, involves several buildings with distinct design characteristics, thus likely leading to different indicator scores for each of them, the evaluation of B.1.2 shall be carried out by identifying representative samples of buildings with similar design features. For each of these representative building designs, a separate assessment should be performed. The overall indicator score for B.1.2 is then estimated as a weighted average of the separate assessment scores, with the weights obtained from the relative occurrence of each building design.

For renovation projects, there are no significant alterations in the assessment compared to newbuild projects. B.1.1 addresses the level of collaboration among actors and the integration of other digital methods and technologies in the renovation project design. In B.1.2, the estimation of the construction costs for premanufacturing and automation indicator comprises manufacturing and installation of new elements, components, parts and materials, but also alterations and deconstruction of existing elements.

The evaluation of the KPI is expected to be performed by the design team, comprising architects, structural engineers and service engineers, potentially seeking the advice of product manufacturers, and main and specialist contractors to identify emerging technologies that are beneficial to the project and produce a correct estimate of costs. The evaluation requires the identification and collection of the building design plans, architectural and structural design drawings, service plans, BoQ and BoM for the whole building(s) or the renovated section of the building(s).

4.4.2 Collaboration and information sharing (B.1.1)

The collaboration and information sharing indicator is evaluated through a dimensionless score, which varies between 0 and 100 based on the BIM maturity stages outlined in PAS 1192-2 (BSI, 2013b) and the ISO 19650-1 (ISO, 2018c). This indicator measures the level of sophistication of the information management processes and the extent to which they establish a collaborative working environment.

As the size and level of complexity of a project grows, the number of involved parties increases. This includes, but is not limited to, clients, owners, operators and managers of the built asset, the design team, construction team and manufacturers delivering the projects, policymakers, regulators, investors, insurers and other external parties (ISO, 2018c). During the whole lifecycle of an asset, these actors produce, exchange and use asset and project information in different forms and with distinct purposes but with a particular order. Digitalisation of such information has been a key driver of collaboration and coordination among distinct disciplines involved in constructing or managing a project (Baldini et al., 2019). Information models are containers of such structured (e.g. geometry, schedules and databases) and unstructured digitalised information (e.g. documents, videos and sounds) related to the delivery phase (i.e. design, construction and commissioning) and operational phase (i.e. operations and maintenance) (ISO, 2018c).

Upon achieving full collaboration or full integration, the indicator rewards the inclusion of disruptive technologies within the design and management processes. The scores are assigned according to the rationale presented in Table 50. The sum of the points cannot exceed 100.

Table 50. B.1.1 score.

Metric	**Score**[1]
Select a single value from the metrics below:	
Low collaboration	+10
Partial collaboration (BIM stage 1)	+30
Full collaboration (BIM stage 2)	+50
Full integration (BIM stage 3)	+75
If [Full collaboration or Full integration] has been selected, check the additional metrics below (multiple selections allowed):	
[Full collaboration or Full integration] + Virtual or Augmented Reality	+20
[Full collaboration or Full integration] + Parametric or Generative Design	+20
[Full collaboration or Full integration] + IoT	+20
[Full collaboration or Full integration] + Digital Twin	+20
Indicator score = Σ (metric scores)	**≤ 100**

[1] If no metric value is satisfied in a single or multiple selection, the assigned score is zero (0).

Source: JRC.

Within the NEB framework, a project characterised by a *low collaboration* is considered low performing. This is, for instance, when there is no sharing of digital information resulting in the production of non-interoperable or paper-based documents. A low BIM maturity (i.e. BIM stage 1) is achieved when digital 2D and 3D information is generated by the individual parties and disciplines but is managed separately by all involved actors. In the case of low BIM maturity, *partial collaboration* is obtained with a limited exchange of data through the adoption of an online shared repository as a common data environment.

A medium BIM maturity (i.e. BIM stage 2) corresponds to a full collaboration across disciplines and specialities. The adopted information management processes are tailored to the specifics of the project and promote a strong collaborative working environment in which the production and exchange of data are coordinated between the parties. Not all the stakeholders operate on the same model. However, information produced through distinct discipline-based software, with different levels of interoperability, is exchanged in common file formats, producing a unified federate model compliant with the ISO 19650-1 (ISO, 2018c). This is stored in a single online shared repository, accessible, editable and maintained by all involved parties.

High BIM maturity (i.e. BIM stage 3) is a level in which deep collaboration among all project stakeholders is achieved through *full integration* of information into a single common shared model, which is centrally stored in a cloud-based environment. The structured database systems of the model are accessible, interrogable, and editable by all project participants, allowing them to work on and modify it simultaneously and in real time. This fully integrated information management process seamlessly follows the evolution of the project across each phase of its lifecycle, including design and construction, refurbishment, operations and maintenance.

Enhanced information management processes where agreed methods are adopted to produce standardised information with predetermined form, quality and delivery schedule, are expected to be beneficial to all involved parties, building a collaborative working environment (BSI, 2013b). Establishing a collaborative environment does not require additional work in terms of information generation and transfer, but implies mutual understanding and trust, as well as a high level of standardisation of the processes to ensure consistent and timely deliverables. Once effectively implemented, this approach ensures a beneficial reduction and anticipation of risks, in terms of costs, mistakes, delays and disputes among actors (BSI, 2013b; ISO, 2018c). BIM stands as the foremost method for generating and managing information models in the current market practices. BIM goes beyond the mere graphical description of the asset (BIM 3D) by incorporating layers of non-graphical information. This comprehensive approach facilitates scheduling and planning across all phases of the lifecycle, encompassing construction, operations, maintenance, and deconstruction. Furthermore, BIM extends its functionality to include the management of activities, costs, supply chains, energy and other critical resource consumption (Sacks et al., 2020). Therefore, higher BIM maturity is expected to result in an optimised quantity of generated information, tailored to specific uses and goals, to increase the reuse of this information and to mitigate the risk of data loss, inconsistencies and misinterpretations.

BIM has been shown to play a pivotal role in fostering the digital transformation of the construction sector, through the integration of other digital methods and technologies such as VR/AR, data-model integration and IoT, digital twinning, parametric and generative design. Recent developments highlight a clear shift away from static BIM models to digital twins that can help improve construction efficiency and reduce maintenance through virtual and augmented reality and IoT integration for continuous monitoring (Tuhaise et al., 2023). *Digital twins* can be employed to improve the quality and speed of decision-making, while significantly reducing errors. This enables rapid iterations and adjustments, resulting in innovative and refined designs. Digital twins can also help to identify and rectify errors early in the design phase, preventing costly mistakes and rework during construction and operation. By creating a real-time, virtual counterpart, digital twins provide a platform for rigorous analysis and simulation, enabling designers to assess the performance of construction materials and components under various conditions. This approach helps to identify potential flaws before they manifest in the physical world, leading to more robust construction practices and anticipating maintenance needs, which allows for timely corrections and mitigations (Opoku et al., 2021). An additional promising ability that digital twinning offers is dynamic life-cycle evaluation supported by past and present information. This allows an accurate end-of-life assessment that could be a key enabler for Circular Economy through component reuse (De Wolf et al., 2024; Brütting et al., 2019).

Parametric design and optimisation techniques are powerful tools to facilitate performance-based design as well as unlock innovative engineering and architectural solutions (Frangedaki et al., 2023). Through parametric design, a set of parameters and constraints can be varied enabling the rapid generation of diverse what-if scenarios that may lead to improved solutions in terms of key performance metrics (e.g. structural integrity, energy efficiency, and functionality) and may unlock innovative design concepts. Novel methods are emerging that make use of machine learning to reduce the computational time required for performance evaluation and behaviour prediction (Maureira et al., 2021; Asgarkhani et al., 2024), as well as mining and learning geometric and other key features that can be systematically encoded using knowledge graphs for the generation of new architectural and structural design (As et al., 2018; Płoszaj-Mazurek et al., 2020; Hayashi and Ohsaki, 2020). These approaches are particularly useful in conceptual design enabling AEC actors (e.g. architects, engineers) to focus on high-level performance targets (as defined in Section 4.2) that require an interdisciplinary and holistic approach.

Figure 49 shows the indicator thresholds used to link indicator scores with performance classes for B.1.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 49. B.1.1 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.1.1 thresholds ($t_{B.1.1}$):	0 ≤		$t_{B.1.1, Acceptable}$ ≥ 30		$t_{B.1.1, Good}$ ≥ 65		$t_{B.1.1, Excellent}$ ≥ 75		≤ 100

Source: JRC.

4.4.3 Premanufacturing and automation (B.1.2)

The premanufacturing and automation indicator is quantitatively evaluated through the premanufactured value (PMV_a) of the assessed project (Cast, 2021). This dimensionless score varies between 0 and 100, for an increasing number of processes that are not executed on the final location on site. Despite its simplicity, PMV_a has proven to be a good metric to quantify the trade-off between innovative and traditional processes, thus, it has been included into the UK Construction Sector Deal's 2018 Implementation Plan as a primary measure for improvement in the construction industry (Cast, 2021).

PMV_a is calculated as the ratio of the premanufactured product and material cost (PMC) to the gross construction cost (GCC), expressed as a percentage.

$$PMV_a = \frac{PMC}{GCC} \cdot 100 \ [\%] \tag{149}$$

PMC comprises the cost of raw material, manufacturing (including factory overhead, running, labour, plant and equipment cost), logistic and transportation of components to site. GCC comprises PMC, preliminaries (from main contractor and sub-contractors) and on-site labour costs (Cast, 2021; CLC, 2018). In GCC, non-construction cost, such as marketing, is not considered. 'Preliminaries' comprise items and expenses necessary to fulfil the terms of the contract that are not allocated to a specific building element or component, such as cost associated with management, staff, site establishment, utility supplies, security, safety and control, insurances, bonds, guarantees and warranties (CLC, 2018). Premanufacturing processes may be conducted off-site, near-site or even on-site, as long as controlled conditions are ensured. As the design evolves from conceptual to detailed, the PMV_a calculation may become more accurate, increasing the availability, granularity and reliability of the data (Jansen van Vuuren and Middleton, 2020). Upon the final definition of the BoQ and BoM, the PMV_a can be further broken down for the specific elements, components, parts and materials (Cast, 2021).

Increasing PMV_a in a project, thus reducing site labour and preliminaries intensity, is expected to enhance efficiency, predictability of the outcomes, productivity, quality, performance, speed, health and safety, while reducing waste, site overheads, cost, time and community disruption (Cast, 2021). Although no established methodologies exist to measure the level of construction automation, PMV_a is considered an informative metric. Indeed, following the definitions of the MMC (MHCLG, 2019), structural and non-structural additive manufacturing, away from or even at the final location on site, is considered a controlled manufacturing process whose costs should be included in PMC. Whereas, innovative site-based construction techniques and robot-assisted operations, although falling outside main premanufacturing categories, improve site-based processes, reducing material wastage, site labour, supervision and overhead cost, thus leading to a higher PMV_a (Cast, 2021; MHCLG, 2019).

In the construction sector, the use of computer-controlled machinery for additive manufacturing, laser cutting and 3D printing of buildings, elements and components is still premature. However, these technologies hold significant potential for offering greater geometric flexibility while improving quality and speed of completion (Baldini et al., 2019). Their evolution is strongly linked with robotics, which boasts a wide-ranging scope, especially in construction, maintenance and deconstruction phases (ECSO, 2021). The advancement of robotics has facilitated the portability of machinery and devices capable of executing various operations on-site, such as welding, casting, bricklaying, assembly or disassembly, either autonomously or under direct operator control (ECSO, 2021). Similarly to additive manufacturing, their adoption remains relatively limited, however, it is steadily increasing (ECSO, 2021).

Performance thresholds for PMV_a may vary depending on the project scale. While some degree of onsite construction is typically required, such as for foundations, achieving complete automation and standardisation of processes is often hindered by the inherent diversity of products within the construction sector (Baldini et al., 2019). Experience in school projects, provided a qualitative three-level rating system with the medium class expected to have a PMV_a above 50% and the high class exceeding 70% (Jansen van Vuuren and Middleton, 2020). A study on residential houses, categorised in low (5 storeys or fewer), mid (6 to 9 storeys) and high rise

(10 storeys or above), indicates an expected baseline PMV_a of 40%, and demonstrated that the implementation of premanufacturing processes and automation enables the attainment of target PMV_a values ranging from 55% to 60%, independently of the building category (Cast, 2021). Following this rationale, the indicator for premanufacturing and automation (B.1.2) is evaluated from PMV_a, according to Equation (150), which results in scores of B.1.2 = 40 for PMV_a = 40%, and B.1.2 = 100 for PMV_a ≥ 80%.

$$B.1.2 = 150 \cdot PMV_a - 20 \quad and \quad 0 \leq B.1.2 \leq 100 \tag{150}$$

Figure 50 shows the indicator thresholds used to link indicator scores with performance classes for B.1.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 50. B.1.2 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
B.1.2 thresholds ($t_{B.1.2}$):	0 ≤	$t_{B.1.2, Acceptable}$ ≥ 40	$t_{B.1.2, Good}$ ≥ 70	$t_{B.1.2, Excellent}$ 100

Source: JRC.

4.4.4 Example (B.1)

In the following example a newbuild project type for residential main use is considered. The assessment is carried out at the building scale and no listed cultural heritage is affected by the project. During the delivery phase, the design team, comprising the architect, structural engineer and service engineers, focus on ensuring spatial coordination of the components realised off-site, simplifying their specification and manufacturing processes and preventing conflicts during assembly. Additionally, in collaboration with contractors and manufactures, the design team pursue an optimised planning and scheduling of the main construction processes, in terms of logistic, transportation and installation of premanufactured products as well as site labour. To achieve this, each party develops specific discipline models that are then integrated into a master model hosted in a shared common data environment. This full collaboration entails B.1.1 = 50.

As shown in Table 51, the total capital cost for the housing project is EUR 3 000 000. Of this cost, 33% is labour cost, and 18% contractor preliminary cost. Premanufactured cost is estimated to be 49% of the capital cost, due to the off-site production in a controlled factory environment for the columns, beams and floor slabs for the structural system, and external walling products, which are all assembled on-site. This value of PMV_a corresponds to B.1.2 = 54. Accordingly, B.1 score is equal to 52 (Equation (148)), which corresponds to the Acceptable performance class (Figure 48) and a performance class score of 40 (Figure 46).

Table 51. Example of B.1 evaluation.

Item	**Value**	**Performance class**
Collaboration and information sharing	Full collaboration	—
Capital cost	EUR 3 000 000	—
Preliminaries	EUR 540 000 (18%)	—
Site labour	EUR 990 000 (33%)	—
Pre-manufacturing costs	EUR 1 470 000 (49%)	—
PMV_a	49%	—
B.1.1	50	(Acceptable)[1]
B.1.2	54	(Acceptable)[1]
B.1	52	Acceptable
$PCS_{B.1}$	40	—

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

4.5 Quality of design and delivery (B.2)

4.5.1 Description and assessment

Under *Quality of design and delivery KPI (B.2)*, the following indicators are assessed:

- *Competencies of design team and contractors (B.2.1)*: the extent to which the project team has relevant skills and experience in delivering improved environmental performance and quality.
- *Responsible material sourcing (B.2.2)*: the extent to which purchased construction products contribute to lower levels of negative environmental, economic and social impact.
- *Compliance with material efficiency opportunities (B.2.3)*: the extent to which the design achieves more efficient use of material resources in structural elements.

In the **general case** when all indicators are considered, B.2 score is evaluated as follows:

$$B.2 = \sum_{j=1}^{3}(w_{B.2.j} \cdot B.2.j) \Big/ \sum_{j=1}^{3}(w_{B.2.j}) = 0.3 \cdot B.2.1 + 0.3 \cdot B.2.2 + 0.4 \cdot B.2.3 \leq 100 \quad (151)$$

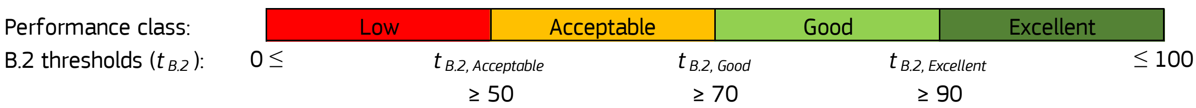
The first indicator (B.2.1) focuses on the competencies necessary to deliver an environmentally improved product. With respect to the requirements in a standard tender process, this criterion values experience in specific technical areas relevant to the sustainability of the final outcomes. This includes expertise in managing technical innovations and utilising multi-criteria green/sustainability or resilience certification schemes, given their increasing prevalence. A competent team is expected to select and specify solutions that align with environmental criteria. The criterion does not aim to exclude companies with less experience and rather encourages their participation in projects with high environmental performance requirements. The goal is to balance risks and foster the project success by ensuring that design and construction teams comprise experienced professionals.

The second indicator (B.2.2) shifts the focus from the procurement of services to the procurement of goods. It promotes the specification and purchase of products with responsible sourcing certification over similar products without certification. Embedding ecological aspects in procurement policies and practices is expected to contribute to sustainable development (ISO, 2017c) and this indicator measures the commitment of the involved organisations to the principles of responsible sourcing.

The third indicator (B.2.3) evaluates whether a project is overdesigned by assessing the quantity of sourced materials in structural elements, thus promoting the optimisation and reduction of embodied resources. Load-bearing systems typically contain an important part of the mass and carbon embodied into the building, which is becoming more relevant also in terms of carbon emissions due to the improvement in the reduction of operational carbon (Röck et al., 2020). Therefore, this indicator provides an evaluation of the structural resource use intensity in the adopted design solutions. To simplify the quantification of this indicator, only floor systems are considered since they typically embody most of the building mass (van der Lugt et al, 2023) and are subjected to well-known loading conditions that are not significantly affected by exogenous factors.

Figure 51 provides the B.2 KPI thresholds adopted in the self-assessment method.

Figure 51. B.2 performance classes and thresholds.



Source: JRC.

The KPI and its three indicators are designed to be implemented at all project scales, types and main uses (Table 48). The assessment of B.2.1 requires the identification of the main actors involved in the delivery and operational phases, therefore, it is not affected by the project classification (i.e. scale, type main use). B.2.2 and B.2.3 are evaluated from an estimation of the BoQ and BoM for the whole building (B.2.2) and the floor systems (B.2.3). To make and manage a harmonised estimate and classification of BoQ and BoM during the design stage, the Level(s) inventory template (Donatello et al., 2021) may be adopted. B.2.2 and B.2.3 evaluation is affected by the project scale and type.

For renovation projects, there are no significant alterations in the assessment compared to newbuild projects for B.2.2 that focuses on new products sourced for the proposed works. For renovation projects, B.2.3 is evaluated only when changes are made to the floor systems. Accordingly, when **renovation projects do not include alterations to the floor system**, B.2.3 is omitted according to Equation (152).

$$B.2 = \sum_{j=1}^{3}\left(w_{B.2.j} \cdot B.2.j\right) \Big/ \sum_{j=1}^{3}\left(w_{B.2.j}\right) = (0.3 \cdot B.2.1 + 0.3 \cdot B.2.2)/0.6 \leq 100 \qquad (152)$$

When a project, classified into the neighbourhood or urban scale, involves several buildings with distinct design characteristics, thus likely leading to different indicator scores for each of them, the evaluation of B.2.2 and B.2.3 shall be carried out by identifying representative samples of buildings with similar design features. For each of these representative building designs, a separate assessment should be performed. The overall score per indicator is then estimated as a weighted average of the separate assessment scores, with the weights obtained from the relative occurrence of each building design (in terms of number of buildings, built area, or other features). For example, when a neighbourhood/urban project includes multiple floor system types, B.2.3 is separately calculated for each system and the overall indicator score is determined as a weighted average of the different floor system scores, with the weights based on the area of each floor type as a percentage of the total gross internal floor area.

When a renovation project, classified into the neighbourhood or urban scale, includes buildings with modified floor systems and buildings without such modifications, the two cases must be assessed separately, as two distinct projects. This is the same approach as the one followed when a neighbourhood/urban scale project includes both types (newbuild, renovation) and/or uses (residential, non-residential) (Section 2.3.2). In all these cases the project should be assessed as multiple ones addressing separately the different classes (e.g. newbuild and residential; newbuild and non-residential; renovation and residential; renovation and non-residential) at the scale of the complete project.

The evaluation of the indicators is conducted by the design team, comprising architects, structural engineers, and service engineers, potentially seeking the advice of product manufacturers, main and specialist contractors, to ensure the traceability of products and materials across their supply chains (B.2.2) or identify feasible alternatives to optimise the design of the floor systems (B.2.3).

The assessment requires the identification and collection of the building design plans, architectural and structural design drawings, service plans, BoQ and BoM for the whole building or the renovated section of the building. For B.2.1, the CVs of the involved parties, official declarations and information related to relevant contracts in the previous years may be necessary to the self-assessor to carry out the indicator quantification.

4.5.2 Competencies of design team and contractors (B.2.1)

The competencies of design team and contractors indicator (B.2.1) is evaluated through a dimensionless score, varying between 0 and 100, based on the PPD (Directive, 2014) and the GPP (COM, 2008) project team competency criteria. The GPP criteria have been defined for office building design, construction and management; however, they are considered hereafter as generally applicable to any building type.

This indicator seeks to ensure that all parties involved in the delivery phase (i.e. design, construction and commissioning), and operational phase (i.e. operations and maintenance), have relevant competencies and experience in each of the technical areas that are relevant to their contractual obligations. Following the GPP approach, four main actors are considered separately due to their distinct roles, differences in the contractual relationships and required competencies: (*i*) project manager, (*ii*) architect, consultant and/or design team, (*iii*) main contractor and specialist contractors, (*iv*) design, build and operate (DBO) contractors and property developers.

The qualitative requirements for contract awarding envisaged by the PPD are categorised as: (*i*) suitability to pursue the professional activity, (*ii*) economic and financial standing, (*iii*) technical and professional ability. The evaluation of these qualitative requirements within a tender procedure is a complex task, often entrusted to a panel with sufficient knowledge and experience to assess competing contractors effectively. Moreover, specific criteria and minimum requirements may be set by national legislation, depending on the size and characteristics of the projects. Therefore, for the scope of the self-assessment tool, a simplified procedure is proposed.

The suitability to pursue the professional activity of any party involved is evaluated with membership in national professional or trade registers. A list of relevant registers and corresponding declarations and certificates is provided in Annex XI of the Directive on public procurement (Directive, 2014).

Requirements concerning economic and financial standing aim to ensure that actors have the necessary economic and financial capacity to execute the contract. The combined capacity of the actors involved is demonstrated, for self-assessment purposes, through a turnover ratio (i.e. ratio of the annual revenue to the expected annual contract value) at least unitary for the three financial years previous to the contract. Moreover, the actors should be protected against third-party claims through an appropriate level of professional risk indemnity insurance. On the other hand, technical and professional ability ensures that actors have adequate human and technical resources and experience to perform the contract to an appropriate quality standard. Combined compliance of the parties involved with these requirements is achieved by holding satisfactory experience of at least four works of a similar size, nature and complexity performed in the five previous years. Project similarity is evaluated in terms of the percentage of the estimated project value. Additionally, an adequate average annual manpower employed in the previous years and specific tools, plant and other technical equipment are necessary and at least one member of the project management or design team must have at least seven years of experience in delivering similar projects.

GPP shifts the focus of the assessment from the three classes of requirements to more environmentally related factors, defining two increasing levels of ambition. The core criteria aim to optimise the trade-off between capacity and economic investments, since the inclusion of green criteria typically entails higher upfront costs compared to standard solutions. Comprehensive criteria, instead, aim at higher innovation goals and more competencies are required. According to GPP, the actors should have relevant competencies and experience in each of the areas that are listed in Table 52, excluding the ones that are not relevant to the specific contract.

Table 52. Competencies and experience required of the main actors involved.

Project manager	
Core criteria	**Comprehensive criteria**
– Project management of building contracts that have met or exceeded the environmental performance requirements set by clients. – Successful identification and management of the delivery of a range of environmental technologies and design innovations required to deliver improved environmental performance and quality. – Involvement in the financial appraisal of environmental technologies and design innovations as part of the delivery of projects.	Beside core criteria, project manager shall have relevant competencies and experience in each of the following: – Projects that included the assessment of building environmental performance using multi-criteria building assessment, reporting and certification schemes. – Use of holistic assessment tools in the design, appraisal and specification of environmentally improved buildings, including life cycle costing (LCC) and life cycle analysis (LCA).
Design team	
Core criteria	**Comprehensive criteria**
– Management of building contracts that have delivered environmental performance that goes beyond minimum building-code requirements regarding the following aspects (to be completed with elements deemed important by the contracting authority and not covered below). – Energy efficient building fabric and services design for newbuild or renovation projects (select as appropriate), including if available measured energy performance data per m^2 from completed projects, including heating, cooling, lighting, hot water and auxiliary equipment. – Installation of Building Energy Monitoring Systems (BEMS) and training building managers on how to analyse and interpret the data collected by the BEMS for energy use pattern diagnostic. – Water efficient services design, including measured water demand per employee from completed projects. – Specification, procurement and installation of low environmental impact construction materials. To include reference to environmental product declarations (EPDs) in compliance with ISO 14025 (ISO, 2006a) or EN 15804 (CEN, 2012). – Development and implementation of staff travel plans, including infrastructure for low emission vehicles and bicycles.	Besides core criteria, architect, consultant and/or design team consortium shall have relevant competencies and experience in each of the following: – Specification and design of renewable and/or high efficiency energy generation equipment. – Installation of Building Energy Monitoring Systems (BEMS), communication of how they can be used to building occupiers and their use to diagnose energy use patterns in buildings. – Bioclimatic architecture and passive design to good thermal and optical comfort, natural air purification etc. – Assessment of building environmental performance using multi-criteria building assessment and certification schemes. – The use of holistic assessment tools in the design and specification of environmentally improved buildings including LCC and LCA. Comparative studies in compliance with ISO 14040 (ISO, 2006b) or 14044 (ISO, 2006c) or EN 15978 (CEN, 2011b). – Design, specification and monitoring to address daylighting and glare, thermal comfort and indoor air quality.

Main and specialist contractors	
Core criteria	**Comprehensive criteria**
– The construction contractor shall have relevant competencies and experience in the completion of building contracts that have been shown to have delivered improved environmental performance. – Energy efficient building fabric and services design for newbuild or renovation projects (select as appropriate), including if available measured energy demand per m^2 from completed projects including heating, cooling, lighting, hot water and auxiliary equipment. This applies in the context of newbuild and/or renovation projects (select as appropriate). – Installation of BEMS and communication of how they work to building managers. – Installation of water efficient services, including if available measured water demand per employee from completed projects. – Procurement, installation and verification of low environmental impact construction materials. – Successful implementation of demolition and site waste management plans in order to minimise waste arisings. Selection and knowledge of off-site treatment options.	Besides core criteria, main and specialist contractors shall have relevant experience in each of the following: – Installation, commissioning and (as relevant) ongoing operation/maintenance of renewable and/or high efficiency energy generation equipment. – Functioning passive design features to achieve low energy use and good thermal and optical comfort, as evidenced by post-occupancy studies. – Procurement, installation and verification of low environmental impact construction materials. Supply chain management to ensure compliance with building assessment and certification systems to support modelled resource efficiency strategies. – Installation of features to address daylighting and glare, thermal comfort and indoor air quality.
Design, build and operate (DBO) contractors, and property developers	
Core criteria	**Comprehensive criteria**
– Management of the construction and operation of buildings that have been shown to have delivered improved environmental performance. – Management of design teams to achieve the permitting and construction of buildings that met client performance requirements, including under DBO arrangements. – Management of main contractors for the construction of buildings that have environmentally improved performance, including under DBO arrangements. – Ongoing facilities management to optimise the performance of buildings, including the use of systems such as BEMS, the contracting of energy managers and the ongoing monitoring/reporting on performance.	Besides core criteria, DBO contractors or property developers shall have relevant experience in management of design teams and/or main contractors to obtain ratings according to multi-criteria building assessment and certification schemes.

Source: Adapted from Dodd et al. (2016).

In the case of design and build contracts, the design team employed should be assessed under the design team criteria. Additionally, when the DBO contractors or property developers operate as facility managers of the building, they shall have certified experience, such as ISO 50001 (ISO, 2018a) or equivalent, in implementing energy management systems (Dodd et al., 2016).

Given the aforementioned PPD and GPP criteria, the scores are assigned according to the rationale indicated in Table 53. The sum of the points cannot exceed 100. For the assessment, the presence in the project team of actors who meet any one of the exclusion rules defined in Directive (2014) automatically results in a value of 0 for the indicator.

Table 53. B.2.1 score.

Metric	Score[1]
Select a single value below:	
Project team comprises at least one actor meeting any of the exclusion criteria of Public Procurement Directive (PPD) (Directive, 2014)	B.2.1 = 0, *No further points to be added.*
No actor of the project team meets any of the exclusion criteria of PPD	*Check next metrics*
Select multiple values below:	
Project manager or design team is qualified and has economic and financial standing as well as technical and professional ability according to PPD.	+25
Main or DBO contractors has suitability, economic and financial standing and technical and professional ability according to PPD.	+25
Select a single value below:	
Project manager meets GPP core criteria.	+15
Project manager meets GPP comprehensive criteria.	+30
Select a single value below:	
Design team meets GPP core criteria.	+10
Design team meets GPP comprehensive criteria.	+20
Select a single value below:	
Main or DBO contractors meets GPP core criteria.	+15
Main or DBO contractors meets GPP comprehensive criteria.	+30
Indicator score = Σ(metric scores)	**≤ 100**

[1] If no metric value is satisfied in a single or multiple selection, the assigned score is zero (0).

Source: JRC.

Figure 52 shows the indicator thresholds used to link indicator scores with performance classes for B.2.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 52. B.2.1 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
B.2.1 thresholds ($t_{B.2.1}$):	0 ≤	$t_{B.2.1, Acceptable}$ ≥ 25	$t_{B.2.1, Good}$ ≥ 55	$t_{B.2.1, Excellent}$ ≥ 70 … ≤ 100

Source: JRC.

4.5.3 Responsible material sourcing (B.2.2)

The responsible material sourcing indicator is quantitatively evaluated as the percentage of construction products from traceable and certified sources. Thus, the indicator varies between 0 and 100. The indicator aims at lowering the levels of negative environmental, economic and social impact, across the supply chain of products, including extraction, processing and manufacture, adopting sustainable development principles and practices in the provision, procurement and traceability of construction materials and components.

To eliminate the use of construction products originating from non-legal sources, a prerequisite of this indicator is that all components, parts and materials integrated in the building must be legally sourced. Failing to meet this requirement leads to a score equal to zero. This is particularly relevant for wood and wood-based products used permanently in the building, and temporarily during construction (e.g. formwork materials). These must be legally harvested and traded as demonstrated through certification schemes, such as those of the Forest Stewardship Council (FSC), the Programme for the Endorsement of Forest Certification (PEFC), the Forest Law Enforcement Governance and Trade (FLEGT), the European Union Timber Regulations (EUTR) or equivalent. Additional certificates may be needed in case of endangered species according to the Convention on International Trade in Endangered Species (CITES) (Dodd et al., 2016).

The BRE Environmental and Sustainability standard (BRE, 2016) provides a comprehensive framework for the assessment of sustainability aspects in the management and procurement practices of an organisation, defining a set of criteria with increasing performance levels. In the current absence of a European standardised method, an approach based on the supply chain management requirements reported in the BRE standard is adopted here as a transitional strategy for the assessment of the responsible material sourcing.

Based on the adopted approach, the assessment is conducted following the identification of the relevant building elements, components, parts, and materials, together with their respective quantities. Within the elements of BoQ, products are identified that are traceable through the supply chain and have an environmental management system in place. Quantities can be measured according to masses, volumes, or values, depending on the most appropriate measure for the assessed product. Consistency is crucial, and when the evaluation aims at driving the decision-making regarding multiple design solutions, the same measure should be consistently adopted in all alternatives.

In the self-assessment tool, products to be considered traceable and responsibly sourced require organisations involved at each stage of their supply chain, including raw material extraction and primary material production, to be certified by an accredited organisation according to ISO 9001 (ISO, 2024b). Moreover, such products must present an environmental management system certified by an accredited organisation according to standards such as ISO 14001 (ISO, 2024a), EU Eco-Management and Audit Scheme (EMAS), FSC and PEFC for wood and wood-based products, among others. Products and materials that are directly reused, fulfil responsible sourcing criteria even without a certification, whereas recycled and recovered ones require a certification for the reprocessing operations. In some cases, it is not possible to ensure the traceability across all the supply chain. In these cases, a possible future improvement of the assessment method consists in considering a different weight depending on the possibility of defining the certification of all or only the major aspects of processing, as currently adopted by some of the BREEAM ([1]) certification schemes.

Recommended thresholds for the percentage of construction products from responsible sourcing may depend on local, regional and/or national market factors (considering the scale of the project). Referring to wood and wood-based materials, GPP sets 25% as an easily achievable target and 70% as a more ambitious goal for public authorities (Dodd et al., 2016). The BRE Environmental and Sustainability standard (BRE, 2016), instead, sets three increasing levels at 60%, 75% and 90%. Considering these sources, Figure 53 shows the indicator thresholds used to link indicator scores with performance classes for B.2.2 in the NEB self-assessment method. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 53. B.2.2 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
B.2.2 thresholds ($t_{B.2.2}$):	$0 \leq$	$t_{B.2.2, Acceptable} \geq 25$	$t_{B.2.2, Good} \geq 55$	$t_{B.2.2, Excellent} \geq 80$	≤ 100

Source: JRC.

4.5.4 Compliance with material efficiency opportunities (B.2.3)

The compliance with material efficiency opportunities is quantitatively evaluated through a dimensionless score, based on the material weight per floor area, which is denoted as g (kN/m^2). This ratio serves as a measure of 'lightness' of structures and anthropogenic (technosphere) mass flows.

Specifically, the assessment of B.2.3 focuses on the horizontal structural systems of buildings (i.e. beams and slabs). The influence of foundations, columns and walls is omitted. The design of these structural components depends significantly on a multitude of exogenous factors such as soil properties, ground water levels and expected actions, which would make the evaluation impractical. Importantly, floor slabs typically embody most of the building mass, estimated between 55 and 65% (van der Lugt et al, 2023), and thus offer a prime opportunity for resource optimisation. In addition, the design of floor systems, in most cases is based on established and well-known loading conditions that are not significantly affected from exogenous factors. Floor slabs are integral components of the structure, providing support for occupants, furnishings, and equipment. However, conventional floor slab designs may result in excessive material use, particularly in buildings with large spans or irregular shapes.

B.2.3 indicator aims at the adoption and implementation of strategies to ensure a reduction of material use in the horizontal structural elements. This, in turn, has a beneficial impact in terms of carbon emissions, resource

[1] https://breeam.com.

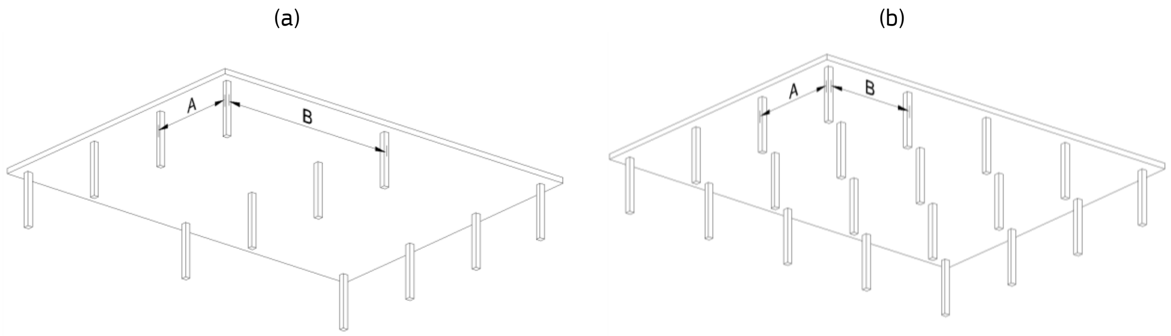
consumption and energy embodied in the building. The estimation of embodied GHG emission into products and processes across the whole life cycle of the building is covered by S.3.2 indicator in the Sustainability dimension, complementing this indicator towards the efficient use of materials and resources.

Preliminary benchmarks have been collected from recent studies (Hart et al., 2021; Svatoš-Ražnjević et al., 2022; Belizario-Silva et al., 2024), which focused on the evaluation of superstructure systems for a variety of material options. Additional information was taken from a survey of 518 buildings (De Wolf et al., 2020), which reports material use intensity considering different structural systems. Since the identified thresholds are not well established, an independent investigation has been conducted for the development of this indicator.

According to this investigation, material usage estimation was carried out for reinforced concrete, timber, and composite floor slabs. Selected construction technologies for each construction material are briefly described in Table A. 1. The selection was based on the degree of maturity of the construction technology, ease of construction and common use in practice.

A multi-span sample area (28 · 21 m = 588 m^2) and two different layouts for supports were considered, as illustrated in Figure 54. For reinforced concrete and composite slabs, spans of 7 · 7 m and 7 · 14 m were considered, respectively, while for timber slabs, the spans were reduced to 6 · 6 m and 6 · 12 m in line with existing construction technologies and good design practice (Schneider et al., 2024). For each construction technology, the slab self-weight along with additional permanent (g_2) and imposed loads (q) were estimated. Loading scenarios with g_2 + q ranging from 4 to 7 kN/m^2 were considered as lower and upper bounds respectively, complying with the design prescriptions of Eurocode 1 – Part 1-1-1 (CEN, 2002a) for most residential and commercial buildings. Assumptions for the material properties were made for each slab configuration. The material designation intends not only to ensure effectiveness for each floor construction technology, but also reflect a typical implementation, avoiding material classes addressed to special structures. A minimum storey height of 2.6 m and a minimum structural fire resistance class of R60 (CEN, 2002b) were considered for all combinations of material, support layout and construction technologies.

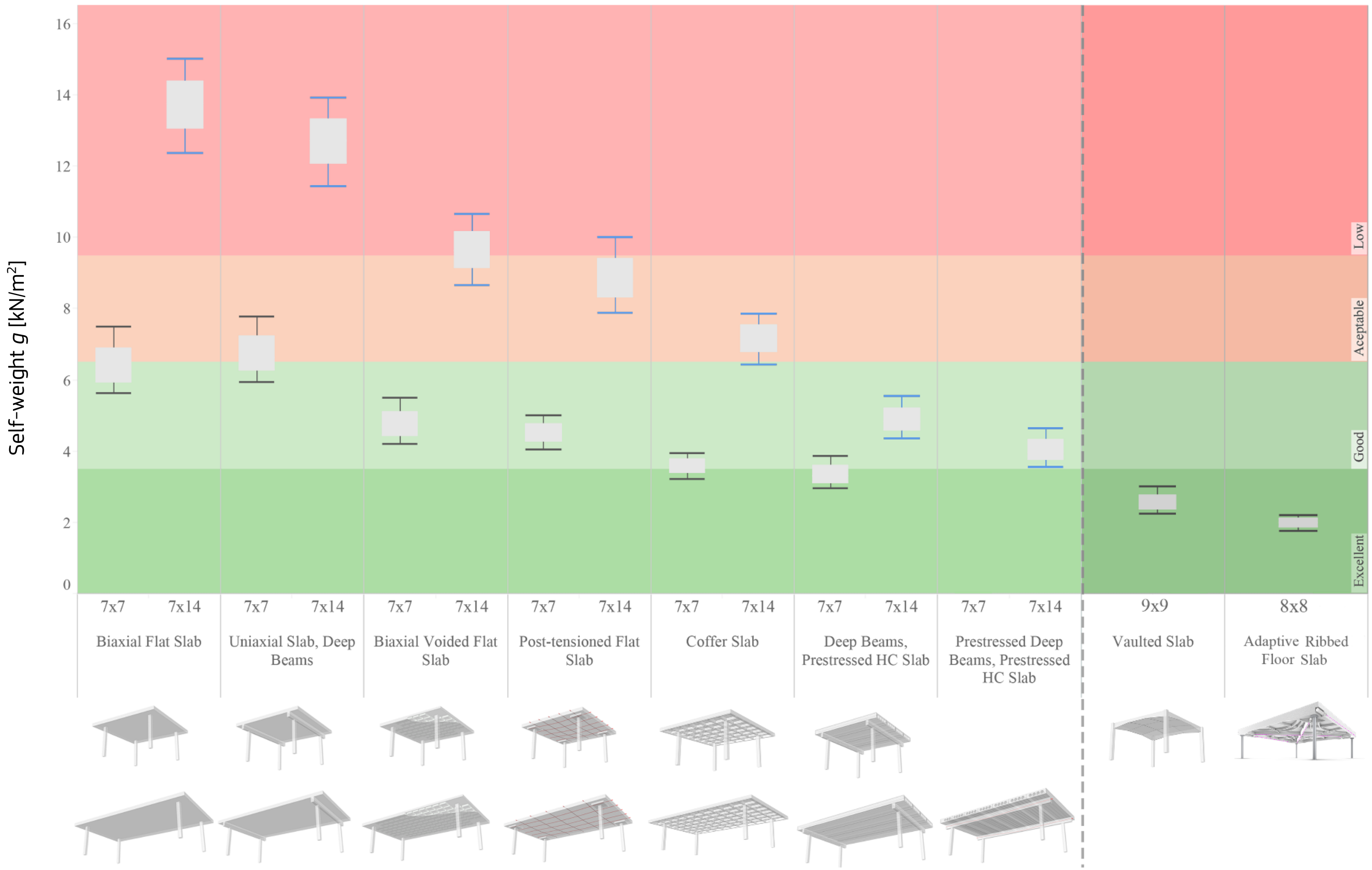
Figure 54. Slab support layout: (a) A · B = 7 · 14 m for reinforced concrete and composite systems and A · B = 6 · 12 m for timber systems; (b) A · B = 7 · 7 m for reinforced concrete and composite systems and A · B = 6 · 6 m for timber systems.



Source: JRC.

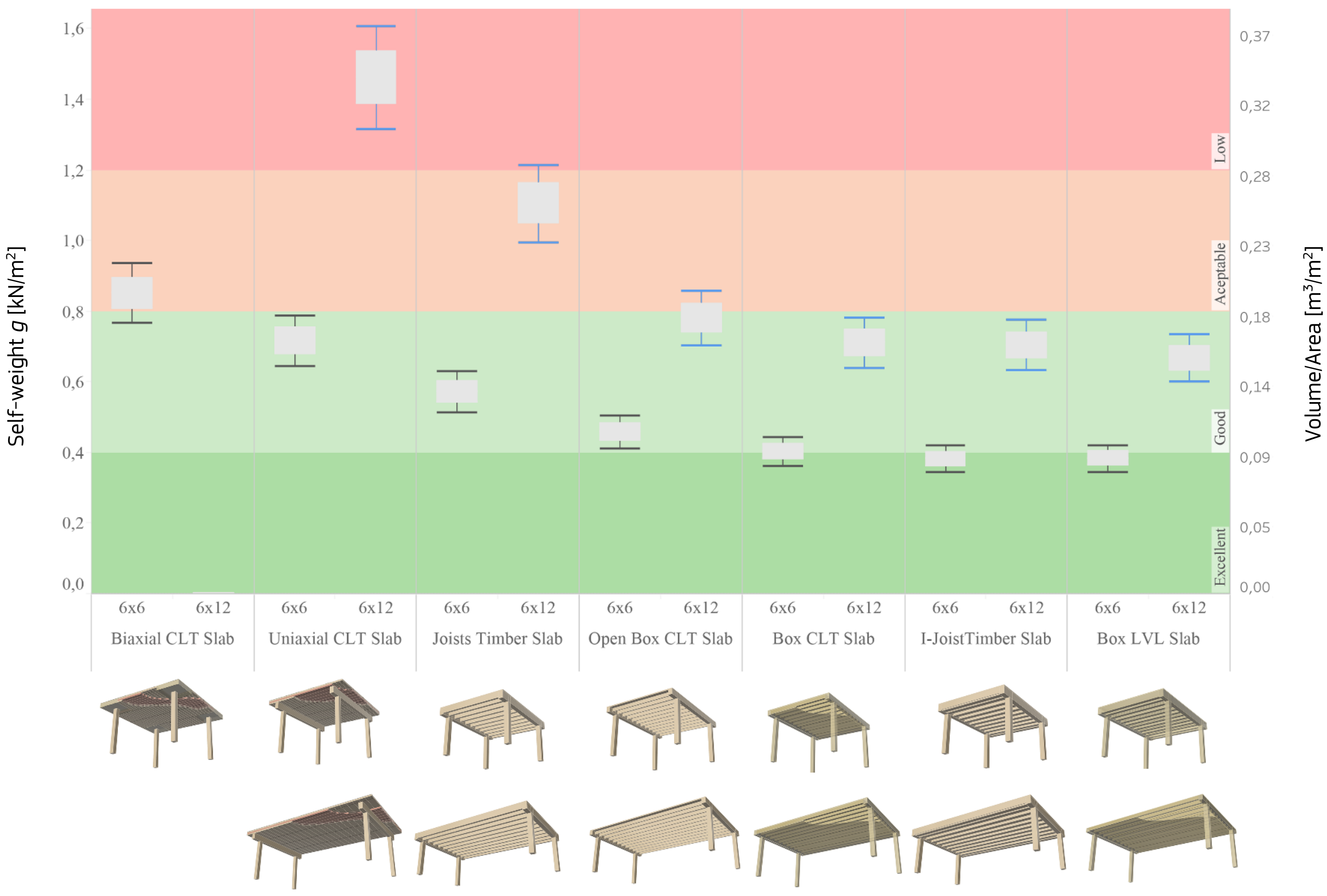
The investigation resulted in detailed maps of floor slab self-weight versus the employed construction technology and main span, as presented in the box plot of Figure 55 for reinforced concrete, Figure 56 for timber, and Figure 57 for composite floor systems. The floor slab cross-sections are detailed in Table A. 1.

Figure 55. Structural resource intensity for concrete slabs (C25/30, C50/60).



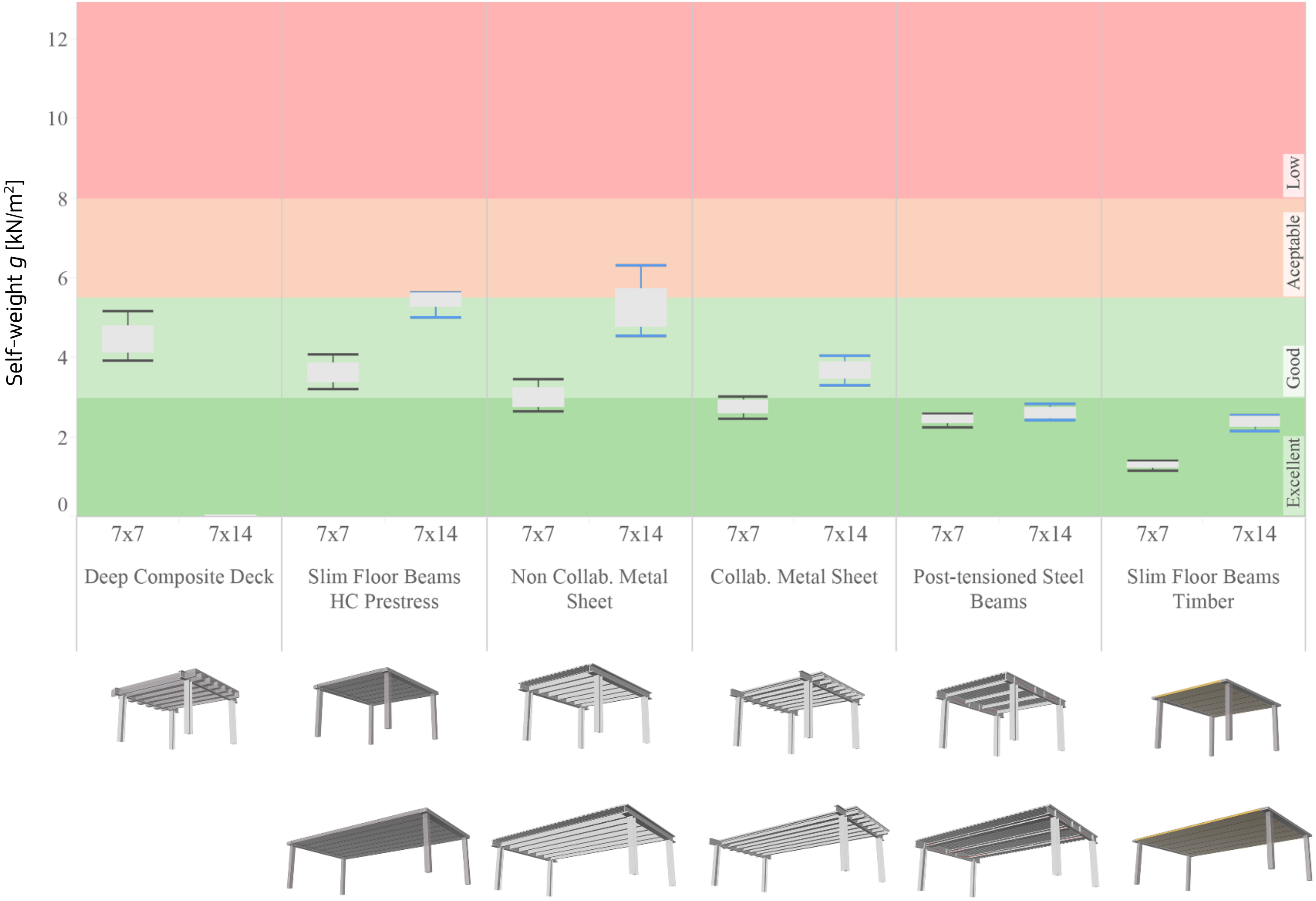
Source: JRC.

Figure 56. Structural resource intensity for timber slabs (C24, GL24h, GL28h, LVL).



Source: JRC.

Figure 57. Structural resource intensity for composite slabs (concrete C25/30, C50/60; steel S235, S355; timber C24, GL24h).



Source: JRC.

For timber floor slabs, a metric of material volume per floor area (in m^3/m^2) is added as a secondary vertical axis, since it is commonly used in practice. However, B.2.3 score for self-assessment is based on the self-weight g. The conversion to material volume per floor area is approximate, considering a density of timber equal to 415 kg/m^3 that is the average value of C24 timber (350 kg/m^3) and laminated veneer lumber (LVL) (480 kg/m^3).

For composite floor slabs, a homogenisation coefficient (a) was employed to convert the weight contribution of other materials to concrete-equivalent values. For a generic material, the homogenisation coefficient is given as:

$$a = \frac{E_i}{\rho_i} \Big/ \frac{E_c}{\rho_c} \tag{153}$$

where, E and ρ are the Young's modulus and density, respectively, for a generic material (i) and concrete (c). Referring to the materials considered in this investigation, for concrete-timber composites, a takes values in the range of 1.9–2.5. The lower value was obtained using C50/60 concrete and LVL, while the upper value using C25/30 concrete and C24 timber. For concrete-steel composites, a takes values in the range of 1.8–2.2. Lower and upper bounds were obtained using C50/60 and C25/30 concrete, respectively. The steel Young's modulus and density did not vary with the considered steel grades (i.e. S235 and S355). The concrete specific weight was set to 25 kN/m^3 regardless of the class.

From the carried-out investigation, it is possible to identify lower and upper bounds of the slab self-weight g for each material, denoted as g_{lb} and g_{ub}, respectively. These correspond to the value of the performance classes Excellent and Low indicated in Table 54.

Table 54. Performance classes expressed in material weight g in kN/m^2 for concrete, timber and composite floor systems.

	Low (g_{ub})	**Acceptable**	**Good**	**Excellent (g_{lb})**
Concrete	$g \geq 9.5$	$9.5 > g \geq 6.5$	$6.5 > g \geq 3.5$	$g < 3.5$
Timber	$g \geq 3.5$	$3.5 > g \geq 2.2$	$2.2 > g \geq 0.9$	$g < 0.9$
Composite	$g \geq 5.0$	$5.0 > g \geq 3.75$	$3.75 > g \geq 2.5$	$g < 2.5$

Source: JRC.

The score of B.2.3 is evaluated using a linear interpolation between the bounds, according to Equation (154). Lower and upper score bounds are $B.2.3_{lb}$ = 30 and $B.2.3_{ub}$ = 80, whereas the slab weight bounds are indicated in Table 54 for each considered material (g_{lb}, g_{ub}). Figure 55–Figure 57 may provide a range of g values as a function of the slab construction technology, main span and material at the early stages of design to evaluate alternative design solutions and improve the indicator score.

$$B.2.3 = \frac{B.2.3_{ub} - B.2.3_{lb}}{g_{ub} - g_{lb}}(g - g_{lb}) + B.2.3_{lb}; \;\; 0 \leq B.2.3 \leq 100 \tag{154}$$

The indicator score bounds have been chosen so that the application of standard practice is expected to result in the Acceptable performance class (Figure 58). Thoughtful design choices in the support distribution and floor shapes enable efficient material use, when common and economical construction technologies are adopted. On the other hand, when programmatic and architectural choices favour large spans for functional reasons (i.e. to improve circulation, daylight penetration, etc.), high performance structural solutions become essential to minimise material consumption.

Higher performance classes can be achieved by employing more advanced design workflows that include parametric design and structural optimisation. Among innovative construction technologies that have a good potential are functionally graded concrete slabs, i.e. slabs with optimised gradient of porosity obtained by placing mineral void formers in the cross-section (Schmeer and Sobek, 2018). This can be thought of as an optimised variant of a voided biaxial slab using mineral void formers, which facilitates recycling compared to conventional solution using plastic void formers (Nigl et al., 2022). This technology has been applied to the design of the foundation and basement slabs of the new Large-scale Construction Robotics Laboratory (LCRL) at the University of Stuttgart (Haufe et al., 2024).

Vaulted floor systems (Hawkins et al., 2019) and rib-stiffened funicular floor systems (Rippmann et al., 2018) are innovative solutions that draw on experience of Gothic master builders, comprising double curved shells and post-tensioned ties between the slab corners to sustain the horizontal thrusts. These solutions are being reconsidered thanks to digital fabrication methodologies that ease construction feasibility of systems characterised by a more complex geometry than conventional flat slabs. Material savings exceeding 50% have been reported compared to conventional flat slabs (Liew et al., 2017).

An emerging approach to structural design involves the strategic integration of sensors and mechanical actuators to design structural systems that can counteract actively the effect of loads. The effect of actuation can be employed to redirect the stress from critically loaded components and reduce deformations. This approach is particularly effective for stiffness-governed design problems, e.g. tall and slender buildings, and long-span floor systems and bridges. Numerical and experimental tests have demonstrated that well-designed adaptive structures, including floor systems, can achieve material and associated emission savings exceeding 50%, compared to equivalent optimised passive solutions (Blandini et al., 2022; Reksowardojo et al., 2024; Senatore and Wang, 2024).

In the box plot map of Figure 55, emerging technologies for concrete slabs are reported on the right side of the dashed line. For vaulted floor systems, values are adapted from a structural design developed by ARUP and Laing O'Rourke on a 9 · 9 m layout (Scott, 2022). The adaptive ribbed slab is an experimental design developed at the University of Stuttgart that uses active tendons integrated in the ribs to counteract the effect of superimposed dead and live load (Reksowardojo et al., 2024). Further information about these systems is given in Table A. 1.

Figure 58 shows the indicator thresholds used to link indicator scores with performance classes for B.2.3. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 58. B.2.3 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.2.3 thresholds ($t_{B.2.3}$):	0 ≤		$t_{B.2.3, Acceptable}$ ≥ 30		$t_{B.2.3, Good}$ ≥ 55		$t_{B.2.3, Excellent}$ ≥ 80		≤ 100

Source: JRC.

4.5.5 Example (B.2)

In the following example a renovation project type for non-residential main use is considered, namely the structural design of a new multi-span 28.0 · 21.0 m concrete slab for an existing office building. The assessment is carried out at the building scale and no listed cultural heritage is affected by the project. A project team involved in the structural design of a multi-span 28.0 · 21.0 m concrete slab for an office building consists of the following members: (*i*) project manager; (*ii*) architect; (*iii*) civil engineer; (*iv*) main contractor.

All the parties are qualified to pursue the professional activity, as demonstrated by their enrolment in national professional or trade registers. The economic and financial standing is demonstrated through a ratio of the annual revenue of the involved parties to their annual contract value higher than one, in the last three years. Moreover, the parties are protected by professional risk indemnity insurances with an appropriate liability limit to provide coverage against claims for loss or damage in the specific current work. The technical and professional capacity of the team is demonstrated through participation in the previous five years in more than four works of the same nature and complexity and with values equal or greater than the value of the current project. Finally, the project manager has more than ten years of experience in delivering similar projects. These criteria are considered sufficient in the self-assessment to satisfy the PPD criteria (Directive, 2014) for both the design team (+25) and contractors (+25). Moreover, the project manager satisfies the comprehensive GPP criteria (+30), having experience in the design of environmentally efficient buildings, as demonstrated by works delivered in the previous five years, expertise in LCA analysis, and certification in well-established multicriteria rating schemes. Other members do not have any specific demonstrable competencies in green technologies, design or construction. Considering this consortium, B.2.1 equals 25 + 25 + 30 = 80 (corresponding to Excellent performance according to Figure 52).

Initially, the team designs a uniaxial slab (Design alternative 1, in Table 55). The slab is supported on beams and has spans of 7.0 and 14.0 m having a layout of column support as shown in Figure 54a. The design is carried out considering a permanent additional load of g_2 = 2.0 kN/m^2 and an imposed live load of q = 3.0 kN/m^2. The design results in 300 m^3 of concrete, expected to be cast in place.

60% of concrete (in terms of volume), including recycled materials, is purchased from organisations with a certificated environmental management system. Accordingly, B.2.2 score is equal to 60 (corresponding to a Good performance class according to Figure 53). The design solution is estimated to require a concrete usage per unit area of g = 12.7 kN/m². Using Equation (154), B.2.3 score is given by:

$$B.2.3 = \frac{30-80}{9.5-3.5}(12.7-3.5)+80 = 3 \tag{155}$$

(achieving Low performance, according to Figure 58). From Equation (151), B.2 score is given by:

$$B.2 = 0.3 \cdot 80 + 0.3 \cdot 60 + 0.4 \cdot 3 = 43 \tag{156}$$

which corresponds to a Low performance class (Figure 51) and a performance class score $PCS_{B.2}$ = 0 (Figure 46).

Then, the project team designs a second configuration (shown in Figure 54b), characterised by a point-supported flat slab with a 7.0 · 7.0 m column grid. For this configuration, the expected volume of concrete reduces to 150 m³. Considering the same percentages of responsibly sourced materials, B.2.2 is kept as 60, whereas the concrete usage per unit area reduces to g = 6.3 kN/m², corresponding to a B.2.3 score of 57 (thus, a Good performance class). Combining the three indicator values, B.2 scores is equal to 65, corresponding to an Acceptable performance class and a performance class score $PCS_{B.2}$ = 40.

The flat slab solution with reduced column spacing performs well, however, the developer perceives a potential value decrease due to a lower space flexibility. The project team designs a third alternative solution with a bidirectional voided slab on 7.0 · 14.0 m bays (configuration shown in Figure 54a). Compared to the first solution, the expected volume of concrete reduces to 188 m³ (-37%), with a material usage of g = 8 kN/m², corresponding to a B.2.3 score of 43. Keeping the same sourcing requirements for indicator B.2.2, B.2 score is found equal to 59, which corresponds to an Acceptable performance class and a performance class score $PCS_{B.2}$ = 40.

Table 55. Example of B.2 evaluation.

Item	**Score**	**Performance class**
Case study 1		
B.2.1	80	(Excellent)[1]
B.2.2	60	(Good) [1]
B.2.3	3	(Low) [1]
B.2	43	Low
$PCS_{B.2}$	0	—
Case study 2		
B.2.1	80	(Excellent) [1]
B.2.2	60	(Good) [1]
B.2.3	57	(Good) [1]
B.2	65	Acceptable
$PCS_{B.2}$	40	—
Case study 3		
B.2.1	80	(Excellent) [1]
B.2.2	60	(Good) [1]
B.2.3	43	(Acceptable) [1]
B.2	59	Acceptable
$PCS_{B.2}$	40	—

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

4.6 Improving building resilience to extreme events (B.3)

4.6.1 Description and assessment

The *Resilience to extreme events KPI (B.3)* looks to evaluate the extent to which the project is resilient to the multiple hazards that can affect it, through the use of three indicators:

- *Hazard characterisation (B.3.1)*: evaluates the reliability of the hazard estimates used in the project design, for all hazards that may affect the project.
- *Hazard resilient design (B.3.2)*: evaluates the reliability of the approach used for the hazard resistant design of structural systems, and what measures are implemented by the design to limit damage and promote rapid recovery.
- *Consequence mitigation (B.3.3)*: extent to which the project design implements measures in place to mitigate the consequences of extreme hazards on functionality and on the user community.

To evaluate B.3, the assessor must first identify which hazards can affect the project. In the NEB self-assessment method, the man-made hazards of fire and blast are considered, together with the following natural hazards: wind, floods (riverine and coastal), earthquakes, landslides, volcanic ash and tsunami. Volcanic hazards other than ashfall are not considered, as it is not safe, nor cost effective, to design buildings to resist other volcanic hazards, such as lahars. For the selected natural hazards, established methods for hazard intensity calculation and numerous hazard maps can be sourced in codes of practice and the global literature. Design codes and/or guidelines exist for design against the chosen hazards, even if not in all countries.

Table 56. Identification of hazards affecting the project.

Hazard	**Selection**
Select man-made hazards of relevance to the project (multiple selections allowed):	
Wind Floods (riverine and coastal) Earthquakes Landslides Volcanic ash Tsunami	
Select man-made hazards of relevance to the project (multiple selections allowed):	
Fire Blast	
Total selections	***n* hazards**

Source: JRC.

B.3.1 and B.3.2 indicators are evaluated separately for each hazard according to adherence with best-practice design guidance, and beyond best-practice standards and guidance. B.3.3 is hazard independent and includes aspects of community and organisational preparedness, evacuation as well as considerations of project function continuity post hazard event. B.3 and the associated indicators can take values between 0 and 100. B.3 score is evaluated according to Equation (157):

$$B.3 = (w_{B.3.1} \cdot B.3.1_h + w_{B.3.2} \cdot B.3.2_h + w_{B.3.3} \cdot B.3.3) \Big/ \sum_{j=1}^{3} (w_{B.3.j}) = \qquad (157)$$

$$= (0.35 \cdot B.3.1_h + 0.35 \cdot B.3.2_h + 0.3 \cdot B.3.3) \leq 100$$

Equation (157) differs from the general form of Equation (2) with regard to the calculation of the first two indicators. Specifically, the values of B.3.1 and B.3.2 that enter Equation (157), correspond to the hazard (*h*) (among the *n* considered hazards of Table 56) that minimises the sum of the two indicators:

$$B.3.1_h + \mathrm{B}.3.2_h = min\{(B.3.1_1 + \mathrm{B}.3.2_1), \ (\dots), \ (B.3.1_n + \mathrm{B}.3.2_n)\}, \qquad h \in \{1,2,\dots n\} \qquad (158)$$

Finally, the performance class of B.3 is assessed, according to the thresholds in Figure 59.

Figure 59. B.3 performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.3 thresholds ($t_{B.3}$):	$0 \leq$		$t_{B.3, Acceptable} \geq 40$		$t_{B.3, Good} \geq 60$		$t_{B.3, Excellent} \geq 85$		≤ 100

Source: JRC.

The KPI and its indicators are designed to be implemented at all project scales, types and main uses (Table 48). The KPI is influenced by the context regarding the identification of hazards expected to affect the projects. The assessment of B.3.1, B.3.2 and B.3.3 is affected by the project scale and type.

When a project, classified into the neighbourhood or urban scale, involves several buildings with distinct design characteristics, thus likely leading to different indicator scores for each of them, the evaluation of B.3.1, B.3.2 and B.3.3 shall be carried out by identifying representative samples of buildings with similar design features. For each of these representative building designs, a separate assessment should be performed. The overall score per indicator is then estimated as a weighted average of the separate assessment scores, with the weights obtained from the relative occurrence of each building design.

For renovation projects, the assessment focuses on the specific aspects of the building and spaces that are affected by the proposed renovation works. However, when indicators and/or metrics address an aspect that has not been altered by the renovation, their evaluation should consider the as-built state (i.e. condition before the intervention is set), as this contributes to the building resilience to extreme events.

The evaluation of the indicators within B.3 KPI is conducted by the design team, comprising architects, engineers and service engineers, seeking the advice of specialist engineers in hazard-resilient design, device manufacturers, main and specialist contractors. The assessment requires the following information to be identified and collected:

- Standards, guidelines and certification scheme documents, as well as any national standards relevant to hazard resilient design. International building codes and standards may need to be sourced if national codes and standards do not exist for a hazard deemed relevant to the project.
- Hazard maps and past hazard event footprints, for identification of hazards of relevance to the project site.
- Detailed information on the procedures followed by the design and engineering team for determining the hazard intensities at the site of the project.
- Detailed information on the design approach followed for the hazard-resilient design of the project.
- Plans of services and information on any back-up systems for water, electricity, gas, their capacity and location.
- Detailed plans of the buildings including information on storage of hazardous materials where relevant.
- Details of insurance policies for insuring against damage from hazards.
- Information on evacuation training of staff and users of the project, evacuation plans and drills.

4.6.2 Hazard characterisation (B.3.1)

The hazard characterisation indicator (B.3.1) evaluates the reliability of the hazard estimates used in the project design, for all hazards that may affect the project.

A value of B.3.1 is evaluated for each hazard *i*, among the *n* identified to be of relevance to the project (Table 56). These hazard-specific indicator values, $B.3.1_i$, are retained for use in the calculation of B.3. The score for each $B.3.1_i$ cannot exceed 100. On some occasions, next to the metrics of the indicator, a "non-applicable" option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects.

Indicative performance classes for the indicator scores are provided in Figure 60. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 60. B.3.1 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
B.3.1 thresholds ($t_{B.3.1}$):	0 ≤	$t_{B.3.1,\ Acceptable}$ ≥ 20	$t_{B.3.1,\ Good}$ ≥ 50	$t_{B.3.1,\ Excellent}$ ≥ 80	≤ 100

Source: JRC.

Table 57 to Table 63 provide the score evaluation of B.3.1$_i$ score for all hazards. For natural hazards, the indicator B.3.1 focuses on the reliability of the estimated hazard intensity measure (IM) for the project. An IM is defined as a measurable characteristic of the hazard that can be used to calculate the forces and actions for the project engineering design. For example, wind speed is an IM, as it is a measurable characteristic of wind and is used in the calculation of pressures acting on structural components. Codes of practice can define one or more IM values for design, each associated with a different mean recurrence interval (MRI) (also called return period). MRI is representative of the average time between occurrences of the IM value at a site. Hence, a high MRI value corresponds to a rare hazard occurrence and a high IM value. Building codes use MRI to set limit states (or performance levels) for the design of buildings with different occupancy and importance. At a minimum, they define a high MRI (and associated IM) for the ultimate limit state design of a building. More commonly, modern hazard-related building codes recommend the explicit consideration of multiple limit-states and hence define multiple MRIs for the design (Fardis, 2013). For example, in Europe, Model Code 2010 (*fib*, 2012), EN 1998-1 (CEN, 2004) and draft of the next generation of Eurocode 8–Part 1, respectively define 4, 3 and 4 limit states for design against earthquake hazards. In the case of European building codes, some flexibility can be included to allow each EU member state to define the minimum number of limit states to be explicitly checked. Designers can, however, choose to adopt more performance levels than the minimum number defined in their national code. The number of limit states used in the project is relevant to the reliability of the hazard resilient design (i.e. to B.3.2, where design for more limit states results in a more reliable performance of the project against the hazard). However, as a consistent approach is used for estimating IM values at different MRI, the number of limit states used in the design is not relevant in the evaluation of hazard reliability.

In the design of a project, use of a single hazard event scenario for the determination of IM value (i.e. a deterministic hazard assessment) is not recommended, as it ignores the multiple hazard sources that may affect the project, and hence does not allow a reliable MRI to be associated with the IM value. For most hazard types, probabilistic hazard maps exist that provide IM estimates for given MRI values. These are based on probabilistic hazard assessments that account for multiple sources of aleatory and epistemic uncertainty in the IM estimation. Most modern codes of practice include such hazard maps, which are commonly developed by national entities, such as geological surveys or meteorological offices.

In general, an Acceptable performance class for B.3.1$_i$ can be achieved if the project design adopts hazard IM estimates derived from code-based hazard maps, e.g. seismic zonation and wind speed maps. However, for some hazards, such as floods, landslides, volcanic ash and tsunami, probabilistic hazard maps may not be available in building codes, as national building codes may not include these hazards in standard design practice. In such cases, probabilistic hazard maps from national entities or from reputable academic literature may be used in designs, leading to an Acceptable performance class. It should be noted that although probabilistic hazard assessment techniques are well-established for some hazards (e.g. earthquakes and wind), they are less well developed for other hazards (e.g. tsunami and landslides). Hence, the use of multiple deterministic hazard scenarios obtained from reputable scientific studies may also be adopted in the absence of any reliable probabilistic hazard studies. However, in the case of design for special structures (e.g. those with high occupancy, those used as evacuation shelters, or those providing critical services in the aftermath of a hazard event) the development of a bespoke probabilistic hazard assessment is desired.

For all hazards considered, higher indicator scores are obtained where bespoke data and hazard models are used in the IM evaluation. In the case of bespoke hazard models, it is expected that the topographical, bathymetric or urban arrangement features that are likely to increase the hazard intensity at a site are accounted for in the IM calculation. If they are not, a lower score will be obtained. Neglecting, in the IM calculation, specific mitigation measures (e.g. coastal defence, enhanced landslide drainage, etc.) in surrounding areas that may reduce the hazard intensity at the project site, is conservative. Hence, this is not included as part of the B.3.1$_i$ scoring criteria.

Physics-based models of the hazard can be used to develop probabilistic hazard assessments, and usually are used to simulate the value of an IM at a project site, the IM time history, and other characteristics of the hazard (e.g. other IMs). These physics-based models take different forms for the different hazard types. For example, for landslide hazard assessment, physics-based models are based on simple mechanical laws used to describe the physical processes leading to the landslide event and the resulting landslide characteristics (Pardeshi et al., 2013).

If the effects of climate change are likely to increase the hazard, then they should also be accounted for in the IM calculation to ensure the resulting design is resilient to future climate scenarios. A higher indicator score is therefore achieved if the IM estimates include climate change effects. Climate change projections are used as input to hazard models for floods and wind (e.g. Zscheischler et al., 2018). The Intergovernmental Panel on Climate Change (IPCC) publishes various scenarios for the Earth's future climate and associated effects. The IPCC scenarios are widely used by the global climate change research community and are defined based on possible future trends in GHG emissions. IPCC presents the latest version of these scenarios, which include, for example: (*i*) the 'ambitious' scenario, with a climate policy aimed at reducing GHG, resulting in emissions declining to net zero by about 2075, and becoming negative after that (RCP2.6 or SSP1-2.6 scenarios in IPCC, 2022), (*ii*) the 'transition' scenario, with a climate policy aimed at stabilising GHG emissions, characterised by a slight rise in emissions before they decline after 2050, but do not reach net zero by 2100 (RCP 4.5 or SSP2-4.5 scenarios in IPCC, 2022), and (*iii*) The 'business-as-usual' scenario, whereby emissions rise steadily, doubling by 2050 and more than triple by the end of the century (RCP 8.5 scenario in IPCC, 2022. These scenarios of emissions provide the input parameters to large scale climate models (e.g. atmosphere-ocean general circulation models, see for example Wigley and Raper, 2001). The climate models are then downscaled to provide finer resolution data for IM assessment at the project site. The downscaling can be carried out either by using empirical relationships between global and regional climate models, or by using higher resolution regional climate models with boundary conditions taken from the larger scale models (Fowler et al., 2007). The downscaled models are used to simulate values for dynamic weather variables, from which the IMs are determined. The simulation is repeated at different time steps in the future (commonly up to 50 or 100 years in the future), to generate frequency exceedance curves for the IM (Cremen et al., 2022).

Extreme hazards can impact a project at the same time as other common hazard effects. Accounting for these in the design is important for the consideration of the full range of scenarios in the resilience assessment. A number of key guidelines, standards, databases and other indicator systems have been consulted to form the basis of B.3.1 indicator. These include ASCE (2020, 2022, 2023b), BAT-ADAPT (OID, 2020), Building Resilience Index (International Finance Corporation, 2023), European Soil Data Centre ([2]), FEMA (2007, 2011b, 2013, 2020), Florida Building Code (International Code Council, 2020), Government of Netherlands (2020), NASA global landslide catalog (NASA, 2019), REDi Floods (ARUP, 2023), REDi Extreme windstorms (ARUP, 2022).

In the case of the man-made hazards, designing for fire and blast does not necessarily require a reliable estimate of the hazard intensity. Instead, design approaches focus on promoting hazard avoidance, providing hazard containment, and limiting the likelihood of progressive failure within structures. In the evaluation of B.3, the values of B.3.1 for blast and fire should take on the same value as the scores achieved for B.3.2 for the respective hazards (Table 63).

Table 57. B.3.1 score for wind hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
A probabilistic hazard map from the national code of practice or from a reputable existing scientific study, is used for the intensity measure (IM) determination.	+20	
A site-specific probabilistic hazard assessment is conducted (as per REDI Extreme windstorms ARUP, 2022, or equivalent)	*Check next metrics.*	
If [site-specific probabilistic hazard assessment] has been selected, select single value below:		
The topographical, bathymetric or urban arrangement features that are likely to increase the hazard intensity at a site are considered.	+40	
The topographical, bathymetric or urban arrangement features that are likely to increase the hazard intensity at a site are not considered.	+30	
If [site-specific probabilistic hazard assessment] has been selected:		
Wind-tunnel tests are conducted to verify the calculated effect of surrounding urban environment/topography on the IM.	+20	
If climate change effects are considered, the IM values for different mean recurrence intervals (MRIs) are calculated through (multiple selections allowed):		

[2] https://esdac.jrc.ec.europa.eu.

Consideration of three climate scenarios (IPCC, 2022): (*i*) business-as-usual (RCP 8.5), (*ii*) the transition scenario (RCP 4.5), (*iii*) the ambitious scenario (RCP2.6).	+15	
Downscaling through use of high-resolution climate models – site specific climate assessment.	+15	
Use of mid-century climate projections (as defined in IPCC, 2022).	+5	
Use of late-century climate projections (as defined in IPCC, 2022).	+10	
The following co-incident hazards are accounted for in the load case scenarios used for design (multiple selections allowed):		
Wind + snow accumulation + ice accretion.	+10	☐
Wind + windborne debris[2].	+10	
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
[2] For windborne debris, simplified methods in codes of practice can be used to assess possible impacts.

Source: JRC.

Table 58. B.3.1 score for flood (coastal and riverine) hazard.

Metric	Score
Select type of hazard assessment:	
Multiple deterministic hazard scenarios obtained from reputable scientific studies and/or past event observations are adopted for the intensity measure (IM) determination.	*Check next metrics.*
Hazard is assessed in a probabilistic context.	*Check next metrics.*
If [multiple deterministic hazard scenarios obtained from reputable scientific studies and/or past event observations], has been selected (single selection allowed):	
The project is classed as a special structure.	+0
The project is not classed as a special structure.	+10
If [hazard is assessed in a probabilistic context] has been selected (single selection allowed):	
A probabilistic hazard map from the national code of practice or from a reputable existing scientific study, is used for the IM determination.	+20
A site-specific probabilistic hazard assessment is conducted.	*Check next metrics.*
If [site-specific probabilistic hazard assessment] has been selected, check the metrics below (single selection allowed):	
The hazard assessment is carried out using past observation data coupled with analytical (or simple) flood models.	+40
The hazard assessment is carried out using past observation data coupled with numerical flood models (hydraulic models).	+50
If [site-specific probabilistic hazard assessment] has been selected, check the metric below:	
Topographical, bathymetric or urban arrangement features that are likely to increase the hazard intensity at a site are accounted for.	+10
Flood characteristics (and/or their time histories) that are relevant to the design are calculated (single selection allowed):	
Indirectly from the IM using a simplified procedure (e.g. ASCE, 2023a can be used to calculate velocities, wave heights, wave period, wavelength from the depth of coastal floods)	+10
Through numerical modelling (hydraulic models)	+20
Climate change effects on sea-level rise and precipitation are considered, and the IM values for different mean recurrence intervals (MRIs) are calculated through (multiple selections allowed):	
Consideration of three climate scenarios (IPCC, 2022): (*i*) business-as-usual (RCP 8.5), (*ii*) the transition scenario (RCP 4.5), (*iii*) the ambitious scenario (RCP2.6).	+15
Downscaling through use of high-resolution climate models - site specific climate assessment.	+15
Use of mid-century climate projections.	+5
Use the late-century climate projections.	+10
The following co-incident hazards are accounted for in the load case scenarios used for design:	
Flooding + debris[1]	+10
Indicator score = Σ(metric scores)	**≤ 100**

[1] Water-borne debris hazard assessment in Urban environment can be conducted as per ASCE/SEI 7-22 Supplement 2 (ASCE, 2023a) section 5.3.9.1.2, FEMA 543 (FEMA, 2007), FEMA P-55 (FEMA, 2011b), or other simplified approach.

Source: JRC.

Table 59. B.3.1 score for earthquake hazard.

Metric	Score
Select single value below:	
A probabilistic hazard map from the national code of practice or from a reputable existing scientific study, is used for the IM determination.	+20
A site-specific probabilistic seismic hazard assessment (PSHA) is conducted:	*Check next metrics.*
If [site-specific probabilistic seismic hazard assessment] has been selected, check the metrics below (multiple selections allowed):	
The hazard assessment is carried out using past observation data coupled with ground motion prediction equations (GMPE).	+40
More than one GMPE is used.	+5
Spatial correlation is accounted for (see Baker and Chen, 2020).	+5
Physics-based earthquake ground-motion simulations (see Taborda and Roten, 2015) are used in the hazard calculation.	+50
The topographical and geological features that are likely to increase the hazard intensity at a site are accounted for in the hazard calculation.	+10
Response spectra and earthquake records used for the design (single selection allowed):	
Standard spectral shapes (uniform hazard spectra) associated with national codes of practice are used in the design and/or as targets for the selection of ground motions.	+10
Conditional mean spectra (e.g. Baker, 2011) are defined from PSHA and are used for design or as targets for the selection of ground motions.	+15
A selection of records is used from physics-based probabilistic seismic hazard assessment (see Bradley et al., 2015 for example).	+15
The following co-incident hazards are accounted for in the load case scenarios used for design:	
An assessment of the liquefaction potential of soils at the project site is conducted.	+15
Indicator score = Σ(metric scores)	**≤ 100**

Source: JRC.

Table 60. B.3.1 score for landslide hazard.

Metric	Score
Select type of hazard assessment:	
Multiple deterministic hazard scenarios obtained from reputable scientific studies and/or past event observations are adopted for the intensity measure (IM) determination.	*Check next metrics.*
Hazard is assessed in a probabilistic context.	*Check next metrics.*
If [multiple deterministic hazard scenarios obtained from reputable scientific studies and/or past event observations] has been selected (single selection allowed):	
The project is classed as a special structure.	+0
The project is not classed as a special structure.	+10
If [hazard is assessed in a probabilistic context] has been selected (single selection allowed):	
A probabilistic hazard map from a reputable existing scientific study, is used for the IM determination.	+20
A site-specific probabilistic landslide hazard assessment is conducted:	*Check next metrics.*
If [site-specific probabilistic landslide hazard assessment] has been selected (single selection allowed):	
The hazard assessment is carried out using past observation data of landslide occurrence and size (see Guzzetti et al., 2005).	+40
Physics-based landslide simulations are used in the hazard calculation (e.g. see Mercogliano et al., 2013).	+50
Landslide characteristics (and/or their time histories) that are relevant to the design are calculated (single selection allowed):	
Indirectly from the IM using a simplified procedure or model.	+15
Through numerical modelling of the landslide.	+25
Climate change effects on precipitation are considered, and the IM values for different mean recurrence intervals (MRIs) are calculated through (multiple selections allowed):	
Consideration of three climate scenarios (IPCC, 2022): (*i*) business-as-usual (RCP 8.5), (*ii*) the transition scenario (RCP 4.5), (*iii*) the ambitious scenario (RCP2.6).	+15
Downscaling through use of high-resolution climate models - site specific climate assessment.	+15
Use of mid-century climate projections.	+5
Use the late-century climate projections.	+10
Indicator score = Σ(metric scores)	**≤ 100**

Source: JRC.

Table 61. B.3.1 score for volcanic ash hazard.

Metric	Score
Select type of hazard assessment:	
Multiple deterministic volcanic ash depth footprints obtained from reputable scientific studies and/or past ashfall events are adopted for the intensity measure (IM) determination.	*Check next metrics.*
Hazard is assessed in a probabilistic context.	*Check next metrics.*
If [multiple deterministic volcanic ash depth footprints obtained from reputable scientific studies and/or past ashfall events] has been selected (single selection allowed):	
The project is classed as a special structure.	+0
The project is not classed as a special structure.	+10
If [hazard is assessed in a probabilistic context] has been selected, select (single selection allowed):	
A probabilistic hazard map of volcanic ash depth from the national code of practice or from a reputable existing scientific study, is used for the IM determination.	+20
A site-specific probabilistic volcanic hazard assessment is conducted using observational data on recurrence.	*Check next metrics.*
If [site-specific probabilistic volcanic hazard assessment] has been selected (single selection allowed):	
Empirical, analytical or simple numerical models (e.g. 1D models) for ashfall spread and deposition (see IAEA, 2016) are used.	+40
Numerical ashfall spread and deposition simulations are carried out using wind field models with three dimensions and time (e.g. Hurst and Davis, 2017).	+50
If [site-specific probabilistic volcanic hazard assessment] has been selected:	
The topographical, urban and geological features that are likely to increase the hazard intensity at a site are accounted for in the hazard calculation.	+10
Climate change effects on wind are considered, and the intensity measure (IM) values for different mean recurrence intervals (MRIs) are calculated through (multiple selections allowed):	
Consideration of three climate scenarios (IPCC, 2022): (*i*) business-as-usual (RCP 8.5), (*ii*) the transition scenario (RCP 4.5), (*iii*) the ambitious scenario (RCP2.6).	+10
Downscaling through use of high-resolution climate models - site specific climate assessment.	+5
Use of mid-century climate projections.	+5
Use the late-century climate projections.	+10
The following co-incident hazards are accounted for in the load case scenarios used for design:	
Volcanic ash and rain.	+10
Indicator score = Σ(metric scores)	**≤ 100**

Source: JRC.

Table 62. B.3.1 score for tsunami hazard.

Metric	Score
Select single value below:	
Multiple deterministic tsunami inundation footprints obtained from reputable scientific studies and/or past tsunami events are adopted for the intensity measure (IM) determination.	+10
A probabilistic hazard map from the national code of practice or from a reputable existing scientific study, is used to determine the tsunami height at the coastline.	+20
A bespoke probabilistic tsunami hazard assessment is conducted using numerical simulations (e.g. Salah et al., 2021) to determine the tsunami height at the coastline.	+40
Inundation characteristics at the project site (i.e. runup, inundation depth, inundation velocity) are calculated from the tsunami height at the coastline using (single selection allowed):	
Empirical runup equations (e.g. McGovern et al. 2018), interpolated inundation depths, and inundation velocities evaluated from ASCE/SEI 7-22 chapter 6 (ASCE, 2022).	+10
The Energy Gradeline Analysis (for inundation depth and runup estimation)[1] and inundation velocity equations from ASCE/SEI 7-22 chapter 6.	+20
Numerical inundation simulations[1].	+30
Climate change effects on sea level rise are considered, and the IM values for different mean recurrence intervals (MRIs) are calculated through (multiple selections allowed):	
Consideration of three climate scenarios (IPCC, 2022): (*i*) business-as-usual (RCP 8.5), (*ii*) the transition scenario (RCP 4.5), (*iii*) the ambitious scenario (RCP2.6).	+10
Downscaling through use of high-resolution climate models - site specific climate assessment.	+15
Use of mid-century climate projections.	+5
Use the late-century climate projections.	+10
The following co-incident hazards are accounted for in the load case scenarios used for design:	

Tsunami inundation + waterborne debris (as per the simplified approach in ASCE/SEI 7-22).	+15
Indicator score = Σ(metric scores)	**≤ 100**

[1] Both the Energy Gradeline Analysis in ASCE/SEI 7-22 chapter 6, and numerical inundation models can take into account any amplifying effects of inundation from topography.

Source: JRC.

Table 63. B.3.1 score for fire and blast.

Indicator	**Score**
If [Fire and/or blast] have been selected in Table 56:	
$B.3.1_{Fire}$ =	$B.3.2_{Fire}$
$B.3.1_{Blast}$ =	$B.3.2_{Blast}$

Source: JRC.

4.6.3 Hazard resilient design (B.3.2)

The hazard resilient design indicator (B.3.2) evaluates the reliability of the approach used for the hazard resistant design of structural systems, and what measures are implemented by the design to limit damage and promote rapid recovery. Indicative performance classes for the indicator scores are provided in Figure 61. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement. A value of B.3.2 is evaluated for each hazard (*i*), among the *n* identified to be of relevance to the project (Table 56). The scoring system for each considered hazard is presented in Table 64 to Table 71, and the score for each $B.3.2_i$ cannot exceed 100. On some occasions, next to the metrics of the indicator, a “non-applicable” option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects.

Figure 61. B.3.2 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
B.3.2 thresholds ($t_{B.3.2}$):	0 ≤	$t_{B.3.2, Acceptable}$ ≥ 20	$t_{B.3.2, Good}$ ≥ 50	$t_{B.3.2, Excellent}$ ≥ 80 ≤ 100

Source: JRC.

Unlike some rating systems (e.g. Building Resilience Index for wind, International Finance Corporation, 2023), the design in the NEB method is not assessed against its performance under a recommended value of IM. Instead, scoring for the hazard resilient design indicator refers either to the national code of practice and/or international best practice code used for the project design. The indicator first seeks to evaluate whether and how the project meets or exceeds the performance criteria set out in the code. As stated in Section 4.6.2, many modern hazard-related building codes are performance-based and recommend that the performance of the project is checked at multiple hazard intensity values, each corresponding to a different MRI value (Fardis, 2013). For example, a code may specify that a building should sustain no damage to its structural elements when subjected to an IM value that occurs very frequently (i.e. at low MRI), and that collapse is avoided for IM values that occur very infrequently (i.e. MRI is very high). The use of performance-based design allows for a more tailored approach, whereas it is needed where prescriptive guidance is not available (e.g. for special structures), and it allows implementation of new technologies. The minimum MRI values associated with each limit state can be defined differently for structures with different functions, importance and occupancy. For example, for a given performance objective, the MRI value assigned to a hospital (which should remain operational after an extreme hazard event) is higher than for a normal residential building. As a consequence, hospitals must satisfy the same limit states as residential buildings, but at higher hazard IM values.

In the case of European building codes, some flexibility is included to allow each EU member state to define the minimum number of limit states to be explicitly checked but life-safety performance must always be checked. Non-compliance with the minimum performance checks stated within national hazard codes (or best international practice if a national code does not exist) results in a score of zero being assigned to B.3.2. Designers can choose to adopt more limit states than the minimum number defined in their national code. This results in a higher indicator score as multiple performance checks result in a more reliable and predictable structural performance, but not a more resilient structure. Higher scores for B.3.2 are also achieved when more advanced, state-of-the-art methodologies are used to design the structural components against the hazard, again providing greater reliability in the structural performance.

To this point, performance-based codes that set minimum (prescriptive) MRI for each performance objective included in the code, have been discussed. However, a designer, in consultation with a client and users, may also decide to set higher performance objectives for their project than those required by the code for the use, occupancy and importance of their project. Design to higher hazard levels will result in a reduction in structural and non-structural damage, facilitating faster recovery of functionality post-hazard event, and hence is given a higher indicator score. Higher scores are also achieved for projects that explicitly consider the safety of non-structural components and mechanical, electrical and plumbing (MEP) system performance. These measures reduce the loss of life during a hazard event and allow the rapid restoration of functionality after a hazard event.

The EU currently does not have a Europe-wide building code for flooding. National building design codes for flood resilience are typically prescriptive, with few allowing performance-based design. ASCE/SEI 7-22 Supplement 2, Table C5.3-4 (ASCE, 2023a) provides flood performance objectives for buildings with different occupancies and importance. It also provides guidance on how to design against foundation scour and flood debris impact. The difficulty of excluding water from the building envelope is recognised in most flood building codes, which allow for two design philosophies to be followed: (*i*) flood resistance in the case of small water depths and velocities, where water is kept out of the building by the building elements, and (*ii*) flood resilience, where some flood resistance is provided, but the water is allowed to enter the building. In the latter case, the design criteria aim to minimise the damage to building materials, services and contents. Guidance for the latter is provided by BS 85500 (BSI, 2015b) and Draft BS 85500 (BSI, 2024), which is used as a reference for the B.3.2 score development for these enhanced design features.

In the case of landslide hazards, it is highlighted that it is not typically cost effective nor are there accepted guidelines for designing to directly resist landslide hazards. The best means of achieving landslide resilience is to site the project on stable ground/slopes that are not susceptible to land sliding. However, with growing urbanisation and pressure on land, the built environment expands into areas with low to moderate landslide hazard. In these cases, according to AGS (2000), several actions can be taken to improve landslide resilience. These do not necessarily involve interventions on the structure, but instead involve intervening to stabilise the landslide, erect defensive barriers, as well as set up monitoring and warning systems. These elements therefore constitute the indicator metrics in the case of landslides.

Similar to the case of landslides, there are no building codes or widely accepted guidelines for the design against volcanic ash. However, it is recognised that projects may be sited in areas where volcanic ash may fall, as ash can be transported large distances from the volcano. Volcanic ash is very heavy when wet, corrosive, it can conduct electricity and be harmful to health. Most existing guidance on ashfall vulnerability focus on the collapse of buildings under the weight of ash, which has a density up to 2000 kg/m^3 when wet (Blong et al., 2017). Some aspects of roof design can help reduce the accumulation of volcanic ash (USGS, 2024), whereas other resilience enhancing measures involve keeping ash out of interiors and protecting HVAC and sensitive equipment. The scoring criteria for resilience to volcanic ash are based on these features.

In the case of tsunami hazards, although no European building code exists, there are two international building codes in Japan and USA for the design of structures of critical importance, essential facilities or structures that act as vertical evacuation towers. The ASCE/SEI 7-22 chapter 6, Tsunami loads and effects (ASCE, 2022), is taken as reference for the development of B.3.2 indicator for tsunami. Additionally, insights from tsunami engineering research are included to provide enhanced design criteria for the evaluation.

Currently, the Eurocodes contain specific parts that deal with the fire resistance of structures. A performance-based approach is possible in the general framework of the Eurocodes, however, is not provided in detail. According to a recent review, Athanasopoulou et al. (2023) shows that fire safety and design regulations vary across EU member states, and that prescriptive methods of design for fire safety in buildings are largely prevalent in practice, even if a performance-based approach is allowed. ISO 23932-1 (ISO, 2018b) presents a performance-based framework for fire safety engineering. It provides significant flexibility to the designer to set the performance objectives (amongst which life-safety is mandatory), and guidance is provided on how this could be done in TR 16576 (ISO, 2017b), which draws on international practice. However, according to Athanasopoulou et al. (2023), the fire engineering community needs further standardisation of several equations and approaches for setting performance criteria. The UK Building Regulations Approved Document B – Fire safety (DLUHC, 2019) is a state-of-art document that provides practical guidance to meeting the technical requirements involved in achieving different performance criteria, for most common buildings and occupancy types. It does not provide information on the fire scenarios to be used, which are part of national regulations. This key reference is used as the basis for the indicator evaluation.

In terms of blast loading, EN 1991-1-7 (CEN, 2006) prescribes the need to design for an internal explosion in projects where gas is burned or regulated, or where explosive material such as explosive gases, or liquids forming explosive vapour or gas are stored or transported. The standard requires the structure to be designed to resist progressive collapse resulting from an internal explosion, in accordance with EN 1990, section 4.4 and annex E (CEN, 2023a). However, an overall approach for design under blast external loads is missing from the standard (Karlos and Solomos, 2013). When blast is from external sources/terrorist attack, the most effective means of protecting a structure is to deter the attack or keep the explosive as far away as possible by maximising the standoff distance. These can be achieved through heightened security and the placing of physical barriers, like bollards or large planters, between the road and the building (Cormie et al., 2020). Apart from avoiding progressive collapse, a number of design features can be implemented to help disperse the blast pressures, and the structure can be 'hardened' to absorb the energy of the attack and to protect valuable assets (Cormie et al., 2020). In the case of blast loading, performance criteria can be set for different blast scenarios (e.g. per ASCE, 2011), where a blast scenario has a defined type and weight of explosive, which is triggered in a specific location outside or within the project boundary. Multiple scenarios should be looked at with a variety of devices that befit the use and size of the building. These scenarios should be chosen as the most probable for the site; e.g. Karlos and Solomos (2013) – table 3 provide maximum charge weights per measure of transportation. The score of B.3.2 for blast is drawn from several sources of literature and international guidance.

Aspects of resilience can be achieved through the provision of redundancy. For example, ensuring that progressive collapse does not occur in the case that one structural element is severely damaged by wind- or water-borne debris, or that the safety of evacuation routes is not compromised if the active protection systems (like sprinklers) fail in case of fire. Aspects of redundancy that affect the design of structural and non-structural components are therefore included in B.3.2 evaluation.

Consideration of climate change effects will typically result in a higher IM value for the project design. Given that this level of IM might happen in the future, its consideration in design will result in a more reliable future performance, as well as an enhanced resilience in the short term. However, the inclusion of climate change effects on hazard characterisation is already part of B.3.1 score (hazard characterisation), and therefore not included in B.3.2.

Development of B.3.2 has been guided by a number of key building codes, standards, guidelines and indicator systems, namely: AGS (2000), ASCE (2020, 2022, 2023a, b), Building Resilience Index (International Finance Corporation, 2023), Cormie et al. (2020), Draft prEN 1998-1-1 (CEN, 2022), Draft prEN 1998-1-2 (CEN, 2023b), FEMA P-424 (FEMA, 2010), FEMA 426/BIPS-06 (FEMA, 2011a), ISO 23932-1 (ISO, 2018b), Karlos and Solomos (2013), REDi Extreme windstorms (ARUP, 2022), TR 16576 (ISO, 2017b), REDi Floods (ARUP, 2023), UK Building Regulations Approved Document B – Fire Safety (DLUHC, 2019).

Table 64. B.3.2 score for resilience to wind hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
Main wind resisting design does not comply with the national building code.	B.3.2i = 0, *No further points to be added.*	
Design of main wind resisting system complies with the national building code.	*Check next metrics.*	
In the project design (single selection allowed):		
One performance objective is explicitly checked.	+20	
Two performance objectives are explicitly checked.	+30	
Three or more performance objectives are explicitly checked.	+40	
In the project design (multiple selections allowed):		
Enhanced performance objectives are used in the design (beyond code requirements).	+60	
Design includes redundancy against loss of one load carrying element from windborne debris impact.	+10	
3D computational/FEM model is used for the design (single selection allowed):		
Model includes the structural components only.	+5	
Model includes structural and non-structural elements.	+10	
Damage limitation is provided through the following design elements (multiple selections allowed):		

Windows >$1m^2$ in area are wind-rated.	+10	☐
An enhanced envelope design is implemented to withstand damage at operational windspeeds, according to FEMA P-424 (FEMA, 2010), chapter 6.3.3 or similar national code.	+15	
Chimneys and/or parapets are reinforced.	+10	☐
Motion control (auxiliary damping devices) is implemented.	+15	
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

Table 65. B.3.2 score for resilience to flood hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
Flood resilience design does not comply with the national building code.	$B.3.2_i$ = 0, *No further points to be added.*	
Design of flood resistance (no water entry) and resilience (allowing water entry) system complies at a minimum with the national building code.	*Check next metrics.*	
In the project design (single selection allowed):		
One performance objective is explicitly checked.	+20	
Two or more performance objectives are explicitly checked.	+30	
In the project design:		
Enhanced performance objectives are used in the design (beyond national code requirements).	+40	
The project also complies with or exceeds the following enhanced design features for structural stability based on ASCE/SEI 7-22 (ASCE, 2022) and BS 85500 (2015, 2024) (multiple selections allowed):		
Structures shall be designed to resist flotation due to buoyancy forces as per ASCE/SEI 7-22 section 5.5.1.	+10	
Structures shall be designed to resist sliding as per ASCE/SEI 7-22 section 5.5.2.	+10	
The floor at ground level (including any lateral support provided at the perimeter) should have the necessary strength to resist uplift forces without excessive deformation or cracking.	+5	
Vertical structural elements are designed to resist debris impact as per ASCE/SEI 7-22 section 5.3.9.	+5	
Design includes redundancy against loss of one load carrying element from waterborne debris impact.	+5	
Foundations are deeper than the scour level predicted using ASCE/SEI 7-22 section 5.3.8.	+10	
The project also complies with or exceeds the following enhanced design features for reducing damage and recovery time based on ASCE/SEI 7-22 and BS 85500 (multiple selections allowed):		
Habitable spaces, and uses particularly vulnerable to flood impacts, should be located above the predicted flood levels.	+5	
A water-resistant external leaf, (e.g. concrete or rendered masonry), is used to limit water ingress.	+5	
Areas likely to be at contact with flood water are built with materials that do not corrode and are water resistant or have low absorption.	+10	
Flood resilient insulation is used under flooring and in cavity walls.	+5	
Water resistance measures/devices are adopted to reduce water ingress through doors and windows, e.g. flood door.	+5	
Damp proof membranes are used to minimise the passage of water through ground floors.	+5	☐
Doors and windows are located above the predicted flood water levels.	+2.5	
Boiler units and heat pumps are located above the predicted flood water levels.	+5	☐
Openings for services are sealed with waterproof materials designed for this purpose.	+2.5	
Electric sockets are located above the flood depth.	+2.5	
Underfloor services containing electrical elements or ferrous materials are avoided.	+2.5	
Non-return valves are used in the drainage system to prevent back-flow of diluted sewage	+2.5	
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

Table 66. B.3.2 score for resilience to earthquake hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
Main earthquake resistant design does not comply with the national building code.	$B.3.2_i$ = 0, *No further points to be added.*	
Design of for earthquake resistance complies with the national building code.	*Check next metrics.*	
In the project design (single selection allowed):		
One performance objective is explicitly checked.	+20	
Two performance objectives are explicitly checked.	+30	
Three or more performance objectives are explicitly checked.	+40	
In the project design:		
Enhanced performance objectives are used in the design (beyond code requirements).	+60	
3D Computational/FEM model used for the design (single selection allowed):		
Structural model meets the criteria in Draft prEN 1998-1-1, section 6.2 (CEN, 2022) and models only the structural elements.	+5	
Structural model meets the criteria in Draft prEN 1998-1-1, section 6.2 and explicitly models both structural and non-structural elements.	+10	
Analysis method (as defined in Draft prEN 1998-1-2, CEN, 2023b) used for the design (single selection allowed):		
Force-based approach.	+0	
Lateral forces method of analysis.	+0	
Response spectrum analysis.	+5	
Non-linear static analysis.	+10	
Non-linear response history analysis with at least 7 earthquake time histories used as input.	+15	
Damage limitation is provided through the following design elements (multiple selections allowed):		
Enhanced damping devices, dissipative or re-centring devices are used in the design.	+15	
Base-isolation is used in the design.	+15	
Separation joints are provided in the design to isolate non-structural from structural elements.	+10	
Main non-structural components are designed or reinforced to limit their damage.	+5	
Critical mechanical components are appropriately anchored to prevent damage under ground shaking.	+5	
Internal fittings and furniture that could fall causing injury, are appropriately anchored to the structure.	+5	
Flexible gas piping is implemented.	+5	☐
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

Table 67. B.3.2 score for resilience to landslide hazard.

Metric	**Score**
Select single value below:	
No interventions are carried out to stabilise the landslide, erect defensive barriers, nor set up monitoring and warning systems.	$B.3.2_i$ = 0, *No further points to be added.*
Landslide mitigation measures are carried out.	*Check next metrics.*
Landslide stabilisation is achieved through (multiple selections allowed):	
Planting of vegetation.	+20
Reshaping the slope.	+40
Installing stabilizing piles or anchors.	+20
Enhanced drainage.	+30
Damage/loss from landslides is mitigated using (multiple selections allowed):	
Rigid debris-resisting barriers.	+30
Flexible barriers.	+20
Monitoring and warning system for landslide.	+40
Indicator score = Σ(metric scores)	**≤ 100**

Source: JRC.

Table 68. B.3.2 score for resilience to volcanic ash hazard.

Metric	Score	Non-applicable[1]
Structural stability (multiple selections allowed):		
The roof structural integrity is checked against local and global collapse from wet volcanic ash load (total ash fall thickness for mean recurrence interval (MRI) of at least 500 years should be assumed for conservatism).	+30	
The capacity of the structural system is checked for stability under the weight of the wet ashfall on the roof.	+30	
Damage/loss from volcanic ash is mitigated using (multiple selections allowed):		
A pitched roof is used.	+10	
Roof covering material is smooth (e.g. sheet metal) and can aid the shedding of ashfall.	+10	
Hoods /covers are installed above HVAC air intake to reduce direct ash ingestion.	+10	☐
Filters are applied to external air intakes.	+10	☐
Air vents in walls and windows have a closing mechanism.	+10	☐
Covers are available for sensitive equipment and computers	+5	☐
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

Table 69. B.3.2 score for resilience to tsunami hazard.

Metric	Score	Non-applicable[1]
Select single value below:		
The project design does not comply with ASCE/SEI 7-22 chapter 6, Tsunami Loads and Effects (ASCE, 2022), **and** the project is an essential or critical facility (risk category III or IV in ASCE/SEI 7-22) or will act as a tsunami vertical evacuation structure.	$B.3.2_i$ = 0, *No further points to be added.*	
The project design does not comply with ASCE/SEI 7-22 chapter 6, Tsunami Loads and Effects, **and** the project is not an essential or critical facility (risk category III or IV in ASCE/SEI 7-22) and will not act as a tsunami vertical evacuation structure.	+0	
The project design complies with ASCE/SEI 7-22 chapter 6, Tsunami Loads and Effects.	*Check next metrics*	
If [The project design complies with ASCE/SEI 7-22 chapter 6, Tsunami Loads and Effects] has been selected (single selection allowed):		
One performance objective is explicitly checked (no global failure nor component failure for mean recurrence interval MRI=2500).	+40	
Two or more performance objectives are explicitly checked.	+50	
Modelling and analysis method used for the design (multiple selections allowed):		
A 3D computational/FEM model is used for the design.	+10	
Prescriptive assessment for global and component stability in ASCE/SEI 7-22 chapter 6.	+10	
Non-linear static analysis appropriate for tsunami loading (e.g. variable depth pushover analysis, Baiguera et al., 2022) used for the global and component stability in ASCE/SEI 7-22 chapter 6.	+20	
Analysis includes modelling the effects of non-structural failure progression.	+15	
Damage limitation is provided through the following enhanced design criteria (multiple selections allowed):		
Separation joints are provided in the design to isolate non-structural from structural elements.	+5	
Non-structural components that pose a large area of resistance to the tsunami flow should be designed to break-away.	+10	☐
Design includes redundancy against loss of one load carrying element from waterborne debris impact.	+10	
Foundations are one third deeper than the scour depth predicted using ASCE/SEI 7-22 chapter 6 (see McGovern et al., 2018).	+10	
All habitable areas and/or essential mechanical and electrical equipment are located outside the area of tsunami inundation or are elevated above the inundation level.	+20	☐
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

Table 70. B.3.2 score for resilience to fire hazard.

Metric	Score	Non-applicable[1]
Select single value below:		
The design does not comply with the national fire safety code.	$B.3.2_i$ = 0, *No further points to be added.*	
A prescriptive design approach that is compliant with the national fire code is used.	+20	
A performance-based design approach is adopted for the fire design, which at minimum meets the mandatory requirements of the national fire code.	+40	
The project also complies with or exceeds the following enhanced design features regarding structural stability for fire (multiple selections allowed):		
Load-bearing elements are designed for minimum fire resistance as per Appendix B (DLUHC, 2019).	+10	
Elements with stability dependence, or which are common to more than one building or compartment meet the criteria of section 7.2a and 7.2b (DLUHC, 2019).	+10	
The project also complies with or exceeds the following enhanced design features regarding inhibiting fire spread within the building:		
Internal linings meet the requirements of Sections 6 (DLUHC, 2019).	+5	
Fire compartment design meets the requirements of Section 8 (DLUHC, 2019) and (single selection allowed):		
Limits fire spread to less than 25% of the floor area of a one storey building, or up to 100% of the floor area in one storey of a multi-storey building.	+5	
Limits fire spread to the room/space of origin, which does not exceed 15% of the floor area of a storey in a building.	+15	
Fire compartment design meets the requirements of Section 8 (DLUHC, 2019) and (multiple selections allowed):		
A sprinkler system that meets criteria of Appendix E (DLUHC, 2019) is adopted for non-residential buildings >30m in height[2].	+10	☐
Evacuation routes are protected, as per Section 2.24 (DLUHC, 2019).	+10	
Refuse chutes and storage are designed to Sections 5.42-5.46 (DLUHC, 2019).	+5	☐
Design of cavities and concealed spaces according to Section 9 (DLUHC, 2019).	+5	☐
Protection of openings (e.g. for utilities) in fire-separating elements, according to Sections 10.1-10.5 and 10.24-10.29 (DLUHC, 2019).	+5	☐
Design to avoid fire spread through ducts and flues meets criteria in Sections 10.6-10.23 (DLUHC, 2019).	+5	☐
Design to avoid fire spread along external walls according to Sections 12.3-12.16 (DLUHC, 2019)[3].	+5	
Design for venting of heat and smoke from basements meets the criteria of Section 18 (DLUHC, 2019).	+5	☐
The project also complies with or exceeds the following enhanced design features regarding inhibiting fire spread to other buildings (multiple selections allowed):		
Sufficient spacing is provided such that the amount of thermal radiation falling on a neighbouring existing building (or possible future building) from window openings and other unprotected areas in the building on fire is insufficient to start a fire (Section 13.4-13.23 in DLUHC, 2019).	+5	☐
Walls common to two buildings are designed as compartment walls (Section 8 in DLUHC, 2019).	+5	☐
Fire spread over roof is restricted (Section 14 in DLUHC, 2019).	+5	
Highly hazardous products that may release polluting or toxic products during fires are placed in specifically designated areas which are fire-protected.	+5	☐
All fixed appliances using controlled combustion and other fixed equipment are constructed and installed according to an appropriate fire safety standard.	+5	
Indicator score = Σ(metric scores)	**≤ 100**	

1 If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
2 The metric can only be considered non-applicable if the building being assessed is not a non-residential building >30m in height.
3 For this metric, external walls of a building include anything located within any space forming part of the wall, any decoration or other finish applied to any external (but not internal) surface forming part of the wall, any windows and doors in the wall (DLUHC, 2019).

Source: JRC.

Table 71. B.3.2 score for resilience to blast hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project has not been designed for blast loading.	$B.3.2_i$ = 0, *No further points to be added.*	
The project is designed for blast loading.	*Check next metrics.*	
Select multiple values below:		
The project is designed to avoid progressive collapse from internal explosions[2].	+20	
The project is designed to avoid progressive collapse from external explosions[2].	+20	
The project design considers a more than two blast scenarios associated with the most likely explosive devices and blast locations external to the building.	+20	
The design adopts a performance-based approach and explicitly considers (single selection allowed):		
Two performance objectives.	+10	
More than two performance objectives.	+20	
For the calculation of blast loading (blast overpressure and duration) (single selection allowed):		
Empirical equations are adopted.	+5	
Phenomenological methods, are adopted.	+10	
Computational fluid dynamics (CFD)-based analyses are adopted.	+20	
Modelling and analysis method used for the design (single selection allowed):		
Blast analysis is based on an equivalent static load approach.	+5	
A dynamic blast response analysis for individual components based on a single-degree-of freedom (SDOF) model is used.	+5	
A dynamic blast response analysis for individual components based on a 3D finite element model of the structure is used.	+10	
Modelling and analysis method used for the design:		
A safety factor of 20% is applied to the charge weights in the blast load calculation to account for uncertainty.	+10	
Damage limitation is provided through the following enhanced design criteria from Cormie et al. (2020) (multiple selections allowed):		
A minimum standoff distance of 15.0 m is provided for residential buildings and of 6.0m for non-residential ones.	+5	
A known standoff distance is achieved through the placement of vehicle security barriers (i.e. traffic bollards, large planters or other physical barriers).	+10	
The exterior building geometry has a convex form.	+5	
The building does not have re-entrant corners, cantilevered upper floors nor set-backs.	+5	
In the design, deep recesses that are accessible from ground level are avoided.	+5	
The minimum amount of glazing compatible with other needs (thermal comfort, lighting etc) is provided.	+5	
The building cladding spans vertically from floor to floor, with direct, robust connections into the structural slabs.[3]	+5	☐
Floor slabs are tied into the structural frame and designed to withstand load reversal.	+10	
Internal protected spaces are provided (space of > 0.6 m^2 per person).	+10	
Critical facilities are located in the most well-defended parts of the building, such as basements.	+10	☐
Glazing is made of laminated glass, or other blast resilient material.	+10	☐
Indicator score = Σ(metric scores)	**≤ 100**	

1 If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
2 Progressive collapse can be checked according to EN 1990, section 4.4 and annex E (CEN, 2023a), or equivalent standard.
3 The metric can be marked as non-applicable only where a building has load bearing walls with no cladding.

Source: JRC.

4.6.4 Consequence mitigation (B.3.3)

This consequence mitigation indicator (B.3.3) evaluates the extent to which the project design has measures in place to mitigate the consequences of extreme natural hazards on functionality and on the user community. The indicator focuses on design aspects that promote survivability (i.e. the availability of early warning) and on measures that can be taken to restore project functionality rapidly after a hazard event (e.g. availability of back-up systems). It is noted that dimensioning of spaces and signage for safe evacuation and emergency communication are considered in the indicator B.5.1 Ease of circulation (Section 4.8.2), and therefore not included here.

B.3.3 is evaluated independently of hazard type, as the integrated metrics are relevant to consequence mitigation from all natural and man-made hazards. Indicative performance classes for the B.3.3 scores are provided in Figure 62. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement. The indicator evaluation is presented in Table 72 and the score B.3.3 cannot exceed 100. On some occasions, next to the metrics of the indicator, a “non-applicable” option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects.

Figure 62. B.3.3 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
B.3.3 thresholds ($t_{B.3.3}$):	$0 \leq$	$t_{B.3.3,\ Acceptable} \geq 20$	$t_{B.3.3,\ Good} \geq 50$	$t_{B.3.3,\ Excellent} \geq 80$ ≤ 100

Source: JRC.

Table 72. B.3.3 score.

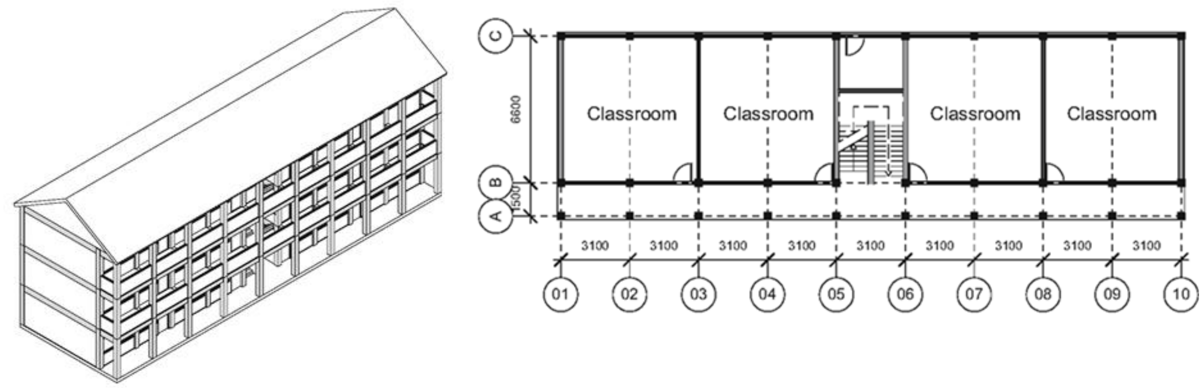
Metric	**Score**	**Non-applicable**[1]
Hazard warning and response (multiple selections allowed):		
Staff and users have access to a warning system for relevant hazards.	+5	
An emergency response plan is in place that accounts for the characteristics of different hazards[2].	+5	
Training is provided to staff on what to do in an emergency and regular evacuation drills are conducted to test emergency operation procedures.	+5	☐
Fire and emergency alarm systems are regularly checked.	+5	
Automatic shut-down systems are in place for utilities or facilities to mitigate the risk of cascading hazards (e.g. fire following earthquakes).	+5	☐
Emergency lighting is available along escape/evacuation routes.	+5	
Each part of an evacuation route, such as exits, corridors and stairs have adequate width for evacuation, given the number of occupants (see Table 3.2 in DLUHC, 2019).	+5	
Vehicle access is provided to the perimeter of the building for fire fighters and emergency services as per Section 15 of DLUHC (2019).	+5	
Fire mains and hydrants are provided as per Section 16 of DLUHC (2019), or more stringent requirement.	+5	
Fire-fighting shafts are provided by the design as per Section 17 of DLUHC (2019).	+5	
Measures to promote rapid recovery (multiple selections allowed):		
A business continuity plan[3] is in place and communicated to staff in non-residential buildings.	+5	☐
The project is insured for hazard-based losses.	+5	
There are generators, fuel storage on-site to power essential systems for > 48 hrs.	+5	
Potable water storage is sufficient to cover project needs for > 48 hrs.	+5	
Backup natural gas supplies are available to cover project needs for > 48 hrs.	+5	☐
Backup communication exists in the form of radio phones or satellite phones are available.	+5	
Off-grid systems are in place to provide continuity of water and energy supply.	+5	
A priority of service agreement is arranged with utility providers.	+5	
Security systems are designed to remain active even with loss of power or have manual over-ride.	+5	
Quick rebooting of server systems and a cloud migration plan to reduce dependence on on-site data storage.	+5	☐
Indicator score = Σ(metric scores)	**≤ 100**	

1 If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
2 The emergency plan should account for the arrival time of wind, tsunami and other hazard events, and account for the characteristics of each hazard.
3 Amongst other items, the business continuity plan should include plans for project cleanup and repair, prioritised restoration of different utilities and services in light of functional recovery.
Source: JRC.

4.6.5 Example (B.3)

The example case study is a newly built high school (non-residential main use) in southern Italy. The assessment is carried out at the building scale and no listed cultural heritage is affected by the project. The school building is a three-storey high reinforced concrete moment resisting frame. A sketch of the school and its ground floor plan are presented in Figure 63. Each floor contains four classrooms with a capacity of 30 children per class. A central staircase provides access to all floors and is located in the central bay of the school. Infill walls are made of unreinforced masonry, and large windows line the back and front of each classroom.

Figure 63. Sketch (left) and ground floor plan (right) of a fictitious high school in Southern Italy, used as an example for B.3 indicator evaluation.



Source: JRC.

From hazard maps available from the National Institute of Geophysics and Volcanology in Italy (INGV), it is observed that the school is sited in an area prone to earthquakes and tsunami, but far enough inland from the coastline (1 km) and any waterways, thus, it is not prone to coastal or riverine flooding. It is also not prone to either landslides or volcanic ash. It is prone to wind, fire and blast hazards.

Table 73. Identification of hazards affecting the project.

Hazard	**Selection**
Select man-made hazards of relevance to the project (multiple selections allowed):	
Wind	√
Floods (riverine and coastal)	
Earthquakes	√
Landslides	
Volcanic ash	
Tsunami	√
Select man-made hazards of relevance to the project (multiple selections allowed):	
Fire	√
Blast	√
Total selections	***5* hazards**

Source: JRC.

The first part of the evaluation involves obtaining a score for the hazard characterisation indicator ($B.3.1_i$) for wind, earthquake and tsunami.

The wind map from the Italian National Annex to Draft prEN 1991-1-4 (CEN, 2021f) is used for the wind design. The school is sited in wind zone 3, which is associated with a fundamental value of the basic wind speed of 27 m/s. According to the code, the basic wind speed corresponds to the characteristic 10-minute mean wind velocity at a height of 10 m above ground level, with an annual probability of being exceeded of 0.02 (MRI = 50 years). This is used to calculate a basic wind velocity of 28 m/s and 30.3 m/s for MRIs of 100 and 500 years, respectively, using equation 6.1 in the Draft prEN 1991-1-4 (using the shape parameter depending on the coefficient of variation of the extreme-value distribution k = 0.2, and the exponent n = 0.5). The code is applied for the wind design of the school building, with wind actions on structures and structural elements determined considering both external and internal wind pressures. No wind tunnel test is carried out for the structure, as it is low-rise and is sited in a semi-rural area.

In the case of earthquake hazard, the latest approved Italian earthquake hazard map is accessed via a GIS platform on INGV website. The map shows the probabilistic seismic hazard and has been derived using more than one ground motion prediction equation. The map provides peak ground acceleration (PGA) values for eight MRI values for any location on the Italian territory. The values of PGA for the school location are plotted against MRI to develop a hazard curve. The earthquake engineering design of the school employs performance checks according to Draft prEN 1998-1-2, table 4.3 (CEN, 2023b) performance criteria, which state that for a school (building class CC3-a) the following performance objectives should be considered: Damage Limitation limit state for MRI = 125 years; Significant Damage limit state for MRI = 700; Near Collapse limit state for MRI = 2500. The hazard curve is used to estimate the PGA values for these MRIs; PGAs are found equal to 0.18g, 0.25g and 0.33g for the three MRI values in increasing order. A 3D finite element model of the school is built, and non-linear static analysis is adopted to analyse, design and check the structure performance under the three earthquake intensity levels.

For the tsunami hazard, a recent study (Basili et al, 2018) conducted as part of a large European Union funded project called TSUMAPS-NEAM, produced a probabilistic tsunami hazard map for the North-eastern Atlantic, Mediterranean and Connected Seas ([3]). This map provides the maximum inundation height at the coastline nearest the school to be 1.78 m for MRI = 2500 years. The NASA Sea level projection tool ([4]) () is used to source a sea level rise projection of 0.31 m for the SSP2-4.5 scenario at mid-century. This is added to the coastal inundation height to become 2.09 m. As only one projection is used, the enhanced criteria score for use of the three projections of climate change is not met. A transect of the topography between the coastline and the school location is found and the Energy Gradeline Analysis of ASCE/SEI 7-22 chapter 6 (ASCE, 2022), is carried out. This results in a tsunami inundation depth prediction of 1.67 m at the site of the school. The waterborne debris impact is designed as per ASCE/SEI 7-22.

The values of B.3.1 for blast and fire are considered equal to the relevant for B.3.2 values for the respective hazards.

The scores for the hazard characterisation indicator (B.3.1) for wind, earthquake and tsunami hazards are provided in Table 74, Table 75 and Table 76, respectively.

Table 74. Example of B.3.1 evaluation for wind hazard.

Metric	Score	Non-applicable[1]
Select single value below:		
A probabilistic hazard map from the national code of practice or from a reputable existing scientific study, is used for the intensity measure (IM) determination.	+20	
A site-specific probabilistic hazard assessment is conducted (as per REDI Extreme windstorms ARUP, 2022, or equivalent)	*Check next metrics.*	
If [site-specific probabilistic hazard assessment] has been selected, select single value below:		
The topographical, bathymetric or urban arrangement features that are likely to increase the hazard intensity at a site are considered.	0	
The topographical, bathymetric or urban arrangement features that are likely to increase the hazard intensity at a site are not considered.	0	
If [site-specific probabilistic hazard assessment] has been selected:		
Wind-tunnel tests are conducted to verify the calculated effect of surrounding urban environment/topography on the IM.	0	
If climate change effects are considered, the IM values for different mean recurrence intervals (MRIs) are calculated through (multiple selections allowed):		
Consideration of three climate scenarios (IPCC, 2022): (*i*) business-as-usual (RCP 8.5), (*ii*) the transition scenario (RCP 4.5), (*iii*) the ambitious scenario (RCP2.6).	0	
Downscaling through use of high-resolution climate models – site specific climate assessment.	0	
Use of mid-century climate projections (as defined in IPCC, 2022).	0	
Use of late-century climate projections (as defined in IPCC, 2022).	0	

[3] http://ai2lab.org/tsumapsneam/interactive-hazard-curve-tool/.
[4] https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool.

The following co-incident hazards are accounted for in the load case scenarios used for design (multiple selections allowed):		
Wind + snow accumulation + ice accretion.	+10	☐
Wind + windborne debris[2].	+10	
Indicator score = Σ(metric scores)	**40**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
[2] For windborne debris, simplified methods in codes of practice can be used to assess possible impacts.

Source: JRC.

Table 75. Example of B.3.1 evaluation for earthquake hazard.

Metric	**Score**
Select single value below:	
A probabilistic hazard map from the national code of practice or from a reputable existing scientific study, is used for the IM determination.	+20
A site-specific probabilistic seismic hazard assessment (PSHA) is conducted:	*Check next metrics.*
If [site-specific probabilistic seismic hazard assessment] has been selected, check the metrics below (multiple selections allowed):	
The hazard assessment is carried out using past observation data coupled with ground motion prediction equations (GMPE).	0
More than one GMPE is used.	0
Spatial correlation is accounted for (see Baker and Chen, 2020).	0
Physics-based earthquake ground-motion simulations (see Taborda and Roten, 2015) are used in the hazard calculation.	0
The topographical and geological features that are likely to increase the hazard intensity at a site are accounted for in the hazard calculation.	0
Response spectra and earthquake records used for the design (single selection allowed):	
Standard spectral shapes (uniform hazard spectra) associated with national codes of practice are used in the design and/or as targets for the selection of ground motions.	+10
Conditional mean spectra (e.g. Baker, 2011) are defined from PSHA and are used for design or as targets for the selection of ground motions.	0
A selection of records is used from physics-based probabilistic seismic hazard assessment (see Bradley et al., 2015 for example).	0
The following co-incident hazards are accounted for in the load case scenarios used for design:	
An assessment of the liquefaction potential of soils at the project site is conducted.	+15
Indicator score = Σ(metric scores)	**45**

Source: JRC.

Table 76. Example of B.3.1 evaluation for tsunami hazard.

Metric	**Score**
Select single value below:	
Multiple deterministic tsunami inundation footprints obtained from reputable scientific studies and/or past tsunami events are adopted for the intensity measure (IM) determination.	0
A probabilistic hazard map from the national code of practice or from a reputable existing scientific study, is used to determine the tsunami height at the coastline.	+20
A bespoke probabilistic tsunami hazard assessment is conducted using numerical simulations (e.g. Salah et al., 2021) to determine the tsunami height at the coastline.	0
Inundation characteristics at the project site (i.e. runup, inundation depth, inundation velocity) are calculated from the tsunami height at the coastline using (single selection allowed):	
Empirical runup equations (e.g. McGovern et al. 2018), interpolated inundation depths, and inundation velocities evaluated from ASCE/SEI 7-22 chapter 6 (ASCE, 2022).	0
The Energy Gradeline Analysis (for inundation depth and runup estimation)[1] and inundation velocity equations from ASCE/SEI 7-22 chapter 6.	+20
Numerical inundation simulations[1].	0
Climate change effects on sea level rise are considered, and the IM values for different mean recurrence intervals (MRIs) are calculated through (multiple selections allowed):	
Consideration of three climate scenarios (IPCC, 2022): (*i*) business-as-usual (RCP 8.5), (*ii*) the transition scenario (RCP 4.5), (*iii*) the ambitious scenario (RCP2.6).	0
Downscaling through use of high-resolution climate models - site specific climate assessment.	0
Use of mid-century climate projections.	+5

Use the late-century climate projections.	0
The following co-incident hazards are accounted for in the load case scenarios used for design:	
Tsunami inundation + waterborne debris (as per the simplified approach in ASCE/SEI 7-22).	+15
Indicator score = Σ(metric scores)	**60**

[1] Both the Energy Gradeline Analysis in ASCE/SEI 7-22 chapter 6, and numerical inundation models can take into account any amplifying effects of inundation from topography.

Source: JRC.

Subsequently, the scores of the hazard resilient design indicator (B.3.2$_i$) are evaluated for wind, earthquake, tsunami, fire and blast.

In the case of wind, the Eurocodes are followed using Nationally Determined Parameters for Italy. Wind design is carried out for the ultimate and serviceability limit states. The same finite element model created for the school building to conduct the seismic design, is adopted to check the wind design. In the model, the infill panels are modelled for in-plane resistance through an equivalent strut approach. Enhanced performance criteria are not used beyond the prescriptions of the code for school structures. The design is checked with respect to EN 1990, section 4.4 and annex E (CEN, 2023a) for progressive collapse, if one column is damaged, and is found to be sufficiently robust (redundant). The windows in the school are large, and are wind rated. There is no chimney in the school, and the parapet walls along the external walkways at the ground and first floor are not reinforced.

For the earthquake resilient design, as stated above, three performance objectives are checked explicitly, and a non-linear static procedure is adopted for the structural analysis. The developed finite element model meets the guidelines of Draft prEN 1998-1-1, section 6.2 (CEN, 2022) and includes the infill walls in the modelling. Enhanced performance criteria are not used beyond the prescriptions of the code for school structures. No damping devices or base-isolation is adopted in the design due to economic constraints. Separation joints are not provided between the infill walls and the surrounding structural elements. The infills and other main non-structural components are not designed or reinforced to limit their damage. HVAC ducting in ceilings is restrained so as not to cause damage to ceiling tiles in the case of ground shaking. Bookcases and heavy furniture are fixed to walls or floors to avoid their toppling in an earthquake event. Flexible gas piping is implemented across the school.

The school governing board wants the school to act as a vertical evacuation tower, to facilitate the evacuation of the school children in the case of tsunami. Hence, the school design is conducted in adherence with ASCE/SEI 7-22 (ASCE, 2022) requirements. Only the collapse limit state is checked for the 2500-year tsunami inundation depth of 1.67 m (see above). The same 3D finite element model is adopted to conduct a variable depth pushover analysis. Out-of-plane failure of the infill walls is calculated from yield line theory, and the effect of their breaking is simulated in the pushover loading histories (see Del Zoppo et al. 2021). The global capacity of the school under tsunami loading exceeds the demand load calculated from the inundation height calculated per ASCE/SEI 7-22, chapter 6, Load Case 2. Hence, the structure satisfies the global checks. However, the component checks show that the shear capacity of the columns needs to be enhanced. Additional shear reinforcement is added throughout the ground floor columns such that the component check is also satisfied. No separation is provided between the infill panels and surrounding frame, and the infills are not specifically designed to breakaway. However, in the analysis, it is observed that they do collapse out-of-plane during the tsunami inundation, as the panels consist of weak material, resulting in a reduction of load on the structural elements. The school does not have living areas. All important equipment that might be damaged when wet is located above the second floor of the building. This includes the boiler.

The school is designed for fire in accordance with the current fire code in Italy (Ministry of the Interior, 2023). This code sets out performance objectives in relation to the importance and function of the building. The school falls in Category IV of the code, and should provide fire resistance such that limited damage to the structure is evident after the fire event. The fire is characterised by a standard fire curve (Section S.2.7 of the code), and to achieve the Damage Limitation limit state, deflections of loaded structural elements must be limited to 1/100 of the member length during the fire. Compartmentalisation is required such that there is no fire spread beyond the originating classroom, and doors and windows must not allow smoke transmission. However, each classroom has a floor area that is 18.1% (i.e. >15%) of the total floor area of one storey. Fire load is calculated per Section S.2.9 of the code from knowledge of the compartment size and combustibles contained. For the fire resistance, the European Standards are used, e.g. EN 13501-2 (CEN, 2023c). The EN standard is prescriptive and results in fire resistance of elements and doors that exceed the requirements of Table B4 in UK Building Regulations Approved Document B (DLUHC, 2019). The lining material requirements of UK Approved Document Bare satisfied. No sprinkler system is installed. The evacuation route is the central staircase of the building, which is only partially surrounded by reinforced concrete walls and does not provide the level of evacuation route protection specified in the UK Approved Document B (DLUHC, 2019). The only cavity is the roof space, and that qualifies as an extensive cavity, according to Section 9 of UK Approved Document B (DLUHC, 2019) as it has a dimension that exceeds 20 m. To achieve fire safety, the cavity needs to be divided up with cavity barriers, but such a measure has not been applied. Openings made by utilities in fire-separating elements are protected, but the ducts are not. The external walls are made of masonry infill, therefore, they exceed the requirement that external wall material should have a density of 300 kg/m^3 or more, which, when tested to BS 476-11 (BSI, 1982), does not flame, and causes a rise in temperature on the furnace thermocouple not exceeding 20°C. The school does not have a basement. The school is in a semi-rural area and at significant distance from any neighbouring building. Moreover, the boundaries of the school walls ensure no future construction is within 30 m of the school building. Thus, fire in the building cannot spread fire to adjacent buildings. All appliances have certification and are installed by qualified professionals. No hazardous substances are kept on the premises due to the presence of children.

In the blast loading design, internal explosions have not been accounted for as there is no kitchen area in the school and no stored gas. The school has a security and safeguarding system in place which makes it extremely difficult for students to bring in any weapon or for someone external to enter the school perimeter. There is a perimeter fence that surrounds the building at a 20m distance from the school footprint. Only scenarios of terrorist attack are considered applicable, with a minimum standoff distance of 20 m. Several scenarios of blast are considered. The worst case is a 100 kg TNT detonation at ground level. An empirical method is used for the design against blast loading. This assumes that the blast detonates at a distance of 20 m, and will apply a uniform pressure across the front of the building. Design charts like those of Unified Facilities Criteria (US Army Corps of Engineers et al., 2008) can be used to calculate the parameters of the blast pressure time history on each façade of the building and at roof level. More details of the calculation approach are available in Karlos and Solomos (2013). In the indicator evaluation, robustness against progressive collapse from damage to an external member is scored (see earlier). The design against blast only considers the collapse performance, and hence is not following a performance-based design. A safety factor of 20% is not applied to the charge weight, and a single degree of freedom approach is considered to check component resistance to the blast load. Accordingly, the design ensures that under the considered blast loading the structure will not collapse. Enhanced design criteria regarding the shape of the building are not met. Significant glazing above minimum needs is provided to maximise light in the classrooms. The floor slab is connected to the frame fully and can sustain reverse loading. The cladding (infill) spans the height of the floor and is also connected to the slabs above and below. Glazing is not made of laminated glass.

The scores for the hazard resilient design indicator (B.3.2) for wind, earthquake, tsunami, fire and blast hazards are provided in Table 77–Table 81.

Table 77. Example of B.3.2 evaluation for resilience to wind hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
Main wind resisting design does not comply with the national building code. Design of main wind resisting system complies with the national building code.	x √ *Check next metrics.*	
In the project design (single selection allowed):		
One performance objective is explicitly checked. Two performance objectives are explicitly checked. Three or more performance objectives are explicitly checked.	0 +30 0	
In the project design (multiple selections allowed):		
Enhanced performance objectives are used in the design (beyond code requirements). Design includes redundancy against loss of one load carrying element from windborne debris impact.	0 +10	
3D computational/FEM model is used for the design (single selection allowed):		
Model includes the structural components only. Model includes structural and non-structural elements.	0 +10	
Damage limitation is provided through the following design elements (multiple selections allowed):		
Windows >1m^2 in area are wind-rated. An enhanced envelope design is implemented to withstand damage at operational windspeeds, according to FEMA P-424 (FEMA, 2010), chapter 6.3.3 or similar national code.	+10 0	☐

Chimneys and/or parapets are reinforced.	0	☐
Motion control (auxiliary damping devices) is implemented.	0	
Indicator score = Σ(metric scores)	**60**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

Table 78. Example of B.3.2 evaluation for resilience to earthquake hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
Main earthquake resistant design does not comply with the national building code.	x	
Design of for earthquake resistance complies with the national building code.	√ *Check next metrics.*	
In the project design (single selection allowed):		
One performance objective is explicitly checked.	0	
Two performance objectives are explicitly checked.	0	
Three or more performance objectives are explicitly checked.	+40	
In the project design:		
Enhanced performance objectives are used in the design (beyond code requirements).	0	
3D Computational/FEM model used for the design (single selection allowed):		
Structural model meets the criteria in Draft prEN 1998-1-1, section 6.2 (CEN, 2022) and models only the structural elements.	0	
Structural model meets the criteria in Draft prEN 1998-1-1, section 6.2 and explicitly models both structural and non-structural elements.	+10	
Analysis method (as defined in Draft prEN 1998-1-2, CEN, 2023b) used for the design (single selection allowed):		
Force-based approach.	0	
Lateral forces method of analysis.	0	
Response spectrum analysis.	0	
Non-linear static analysis.	+10	
Non-linear response history analysis with at least 7 earthquake time histories used as input.	0	
Damage limitation is provided through the following design elements (multiple selections allowed):		
Enhanced damping devices, dissipative or re-centring devices are used in the design.	0	
Base-isolation is used in the design.	0	
Separation joints are provided in the design to isolate non-structural from structural elements.	0	
Main non-structural components are designed or reinforced to limit their damage.	0	
Critical mechanical components are appropriately anchored to prevent damage under ground shaking.	+5	
Internal fittings and furniture that could fall causing injury, are appropriately anchored to the structure.	+5	
Flexible gas piping is implemented.	+5	☐
Indicator score = Σ(metric scores)	**75**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

Table 79. Example of B.3.2 evaluation for resilience to tsunami hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project design does not comply with ASCE/SEI 7-22 chapter 6, Tsunami Loads and Effects (ASCE, 2022), **and** the project is an essential or critical facility (risk category III or IV in ASCE/SEI 7-22) or will act as a tsunami vertical evacuation structure.	x	
The project design does not comply with ASCE/SEI 7-22 chapter 6, Tsunami Loads and Effects, **and** the project is not an essential or critical facility (risk category III or IV in ASCE/SEI 7-22) and will not act as a tsunami vertical evacuation structure.	0	
The project design complies with ASCE/SEI 7-22 chapter 6, Tsunami Loads and Effects.	√ *Check next metrics*	

If [The project design complies with ASCE/SEI 7-22 chapter 6, Tsunami Loads and Effects] has been selected (single selection allowed):		
One performance objective is explicitly checked (no global failure nor component failure for mean recurrence interval MRI=2500).	+40	
Two or more performance objectives are explicitly checked.	0	
Modelling and analysis method used for the design (multiple selections allowed):		
A 3D computational/FEM model is used for the design.	+10	
Prescriptive assessment for global and component stability in ASCE/SEI 7-22 chapter 6.	0	
Non-linear static analysis appropriate for tsunami loading (e.g. variable depth pushover analysis, Baiguera et al., 2022) used for the global and component stability in ASCE/SEI 7-22 chapter 6.	+20	
Analysis includes modelling the effects of non-structural failure progression.	+15	
Damage limitation is provided through the following enhanced design criteria (multiple selections allowed):		
Separation joints are provided in the design to isolate non-structural from structural elements.	0	
Non-structural components that pose a large area of resistance to the tsunami flow should be designed to break-away.	0	☐
Design includes redundancy against loss of one load carrying element from waterborne debris impact.	+10	
Foundations are one third deeper than the scour depth predicted using ASCE/SEI 7-22 chapter 6 (see McGovern et al., 2018).	0	
All habitable areas and/or essential mechanical and electrical equipment are located outside the area of tsunami inundation or are elevated above the inundation level.	+20	☐
Indicator score = Σ(metric scores)	**100**	

1 If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

Table 80. Example of B.3.2 evaluation for resilience to fire hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The design does not comply with the national fire safety code.	x	
A prescriptive design approach that is compliant with the national fire code is used.	+20	
A performance-based design approach is adopted for the fire design, which at minimum meets the mandatory requirements of the national fire code.	0	
The project also complies with or exceeds the following enhanced design features regarding structural stability for fire (multiple selections allowed):		
Load-bearing elements are designed for minimum fire resistance as per Appendix B (DLUHC, 2019).	+10	
Elements with stability dependence, or which are common to more than one building or compartment meet the criteria of section 7.2a and 7.2b (DLUHC, 2019).	+10	
The project also complies with or exceeds the following enhanced design features regarding inhibiting fire spread within the building:		
Internal linings meet the requirements of Sections 6 (DLUHC, 2019).	+5	
Fire compartment design meets the requirements of Section 8 (DLUHC, 2019) and (single selection allowed):		
Limits fire spread to less than 25% of the floor area of a one storey building, or up to 100% of the floor area in one storey of a multi-storey building.	+5	
Limits fire spread to the room/space of origin, which does not exceed 15% of the floor area of a storey in a building.	0	
Fire compartment design meets the requirements of Section 8 (DLUHC, 2019) and (multiple selections allowed):		
A sprinkler system that meets criteria of Appendix E (DLUHC, 2019) is adopted for non-residential buildings >30m in height[2].	10	☒
Evacuation routes are protected, as per Section 2.24 (DLUHC, 2019).	0	
Refuse chutes and storage are designed to Sections 5.42-5.46 (DLUHC, 2019).	0	☐
Design of cavities and concealed spaces according to Section 9 (DLUHC, 2019).	0	☐
Protection of openings (e.g. for utilities) in fire-separating elements, according to Sections 10.1-10.5 and 10.24-10.29 (DLUHC, 2019).	+5	☐
Design to avoid fire spread through ducts and flues meets criteria in Sections 10.6-10.23 (DLUHC, 2019).	0	☐
Design to avoid fire spread along external walls according to Sections 12.3-12.16 (DLUHC, 2019)[3].	+5	

Design for venting of heat and smoke from basements meets the criteria of Section 18 (DLUHC, 2019).	+5	☒
The project also complies with or exceeds the following enhanced design features regarding inhibiting fire spread to other buildings (multiple selections allowed):		
Sufficient spacing is provided such that the amount of thermal radiation falling on a neighbouring existing building (or possible future building) from window openings and other unprotected areas in the building on fire is insufficient to start a fire (Section 13.4-13.23 in DLUHC, 2019).	+5	☐
Walls common to two buildings are designed as compartment walls (Section 8 in DLUHC, 2019).	+5	☒
Fire spread over roof is restricted (Section 14 in DLUHC, 2019).	0	
Highly hazardous products that may release polluting or toxic products during fires are placed in specifically designated areas which are fire-protected.	+5	☒
All fixed appliances using controlled combustion and other fixed equipment are constructed and installed according to an appropriate fire safety standard.	+5	
Indicator score = Σ(metric scores)	**95**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
[2] The metric can only be considered non-applicable if the building being assessed is not a non-residential building >30m in height.
[3] For this metric, external walls of a building include anything located within any space forming part of the wall, any decoration or other finish applied to any external (but not internal) surface forming part of the wall, any windows and doors in the wall (DLUHC, 2019).

Source: JRC.

Table 81. Example of B.3.2 evaluation for resilience to blast hazard.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project has not been designed for blast loading.	x	
The project is designed for blast loading.	√ *Check next metrics.*	
Select multiple values below:		
The project is designed to avoid progressive collapse from internal explosions[2].	0	
The project is designed to avoid progressive collapse from external explosions[2].	+20	
The project design considers a more than two blast scenarios associated with the most likely explosive devices and blast locations external to the building.	+20	
The design adopts a performance-based approach and explicitly considers (single selection allowed):		
Two performance objectives.	0	
More than two performance objectives.	0	
For the calculation of blast loading (blast overpressure and duration) (single selection allowed):		
Empirical equations are adopted.	+5	
Phenomenological methods, are adopted.	0	
Computational fluid dynamics (CFD)-based analyses are adopted.	0	
Modelling and analysis method used for the design (single selection allowed):		
Blast analysis is based on an equivalent static load approach.	0	
A dynamic blast response analysis for individual components based on a single-degree-of freedom (SDOF) model is used.	+5	
A dynamic blast response analysis for individual components based on a 3D finite element model of the structure is used.	0	
Modelling and analysis method used for the design:		
A safety factor of 20% is applied to the charge weights in the blast load calculation to account for uncertainty.	0	
Damage limitation is provided through the following enhanced design criteria from Cormie et al. (2020) (multiple selections allowed):		
A minimum standoff distance of 15.0 m is provided for residential buildings and of 6.0m for non-residential ones.	+5	
A known standoff distance is achieved through the placement of vehicle security barriers (i.e. traffic bollards, large planters or other physical barriers).	+10	
The exterior building geometry has a convex form.	0	
The building does not have re-entrant corners, cantilevered upper floors nor set-backs.	0	
In the design, deep recesses that are accessible from ground level are avoided.	+5	
The minimum amount of glazing compatible with other needs (thermal comfort, lighting etc) is provided.	0	

The building cladding spans vertically from floor to floor, with direct, robust connections into the structural slabs.[3]	+5	☐
Floor slabs are tied into the structural frame and designed to withstand load reversal.	+10	
Internal protected spaces are provided (space of > 0.6 m^2 per person).	0	
Critical facilities are located in the most well-defended parts of the building, such as basements.	+10	☒
Glazing is made of laminated glass, or other blast resilient material.	0	☐
Indicator score = Σ(metric scores)	**95**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
[2] Progressive collapse can be checked according to EN 1990, section 4.4 and annex E (CEN, 2023a), or equivalent standard.
[3] The metric can be marked as non-applicable only where a building has load bearing walls with no cladding.

Source: JRC.

Finally, the consequence mitigation indicator (B.3.3) is evaluated. In terms of hazard warnings, the school is within earshot of tsunami warning towers and is also equipped with fire alarms. The location is not susceptible to landslides and so there is no need for a warning. Through the Italian Civil Protection and police, respectively, the school receives warnings of severe weather conditions and any terrorist threats. An emergency response plan for terrorist or gunman attack is present in the school, and teachers are trained on what to do in such events. Fire alarm and evacuation drills take place once a month, and tsunami evacuation practice to upper floors in the schools is practiced once a year. Automatic shutdown systems are not in place for utilities. Emergency lighting for evacuation routes is not provided. There are four classrooms with 30 children each at each storey. There are also two teachers on average per storey. Hence, from Table 3.3 of UK Approved Document B (DLUHC, 2019), the stair width for phased evacuation should be a minimum of 1.20 m wide. Considering the plan in Figure 63, this requirement is met. Sufficient fire hydrants and access is provided by the design to fire fighters. No fire shaft is however present. The school has an arrangement with a nearby school that in case of shut down, the other school will host the children such that education continuity can be ensured. The school is not insured against natural hazards. The school has a back-up generator and water tank on site that can provide 48 hours of independence from the grid. However, it does not have gas storage on site, access to off grid services or a pre-arranged priority of service agreement with local utility companies. The teachers have access to a satellite phone, which is provided to the school as a precaution by the local council. Finally, the security system can function if there is loss of energy, but no fast reboot system is put in place for the school computing systems. The evaluation of B.3.3 is shown in Table 82.

Table 82. Example of B.3.3 evaluation.

Metric	**Score**	**Non-applicable**[1]
Hazard warning and response (multiple selections allowed):		
Staff and users have access to a warning system for relevant hazards.	+5	
An emergency response plan is in place that accounts for the characteristics of different hazards[2].	+5	
Training is provided to staff on what to do in an emergency and regular evacuation drills are conducted to test emergency operation procedures.	+5	☐
Fire and emergency alarm systems are regularly checked.	+5	
Automatic shut-down systems are in place for utilities or facilities to mitigate the risk of cascading hazards (e.g. fire following earthquakes).	0	☐
Emergency lighting is available along escape/evacuation routes.	0	
Each part of an evacuation route, such as exits, corridors and stairs have adequate width for evacuation, given the number of occupants (see Table 3.2 in DLUHC, 2019).	+5	
Vehicle access is provided to the perimeter of the building for fire fighters and emergency services as per Section 15 of DLUHC (2019).	+5	
Fire mains and hydrants are provided as per Section 16 of DLUHC (2019), or more stringent requirement.	+5	
Fire-fighting shafts are provided by the design as per Section 17 of DLUHC (2019).	0	
Measures to promote rapid recovery (multiple selections allowed):		
A business continuity plan[3] is in place and communicated to staff in non-residential buildings.	+5	☐
The project is insured for hazard-based losses.	0	
There are generators, fuel storage on-site to power essential systems for > 48 hrs.	+5	
Potable water storage is sufficient to cover project needs for > 48 hrs.	+5	

Backup natural gas supplies are available to cover project needs for > 48 hrs.	+5	☒
Backup communication exists in the form of radio phones or satellite phones are available.	+5	
Off-grid systems are in place to provide continuity of water and energy supply.	0	
A priority of service agreement is arranged with utility providers.	0	
Security systems are designed to remain active even with loss of power or have manual over-ride.	+5	
Quick rebooting of server systems and a cloud migration plan to reduce dependence on on-site data storage.	0	☐
Indicator score = Σ(metric scores)	**65**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
[2] The emergency plan should account for the arrival time of wind, tsunami and other hazard events, and account for the characteristics of each hazard.
[3] Amongst other items, the business continuity plan should include plans for project cleanup and repair, prioritised restoration of different utilities and services in light of functional recovery.

Source: JRC.

Having evaluated the scores for each indicator, the indicator values are used to calculate the KPI score for B.3 (Table 83). B.3. score corresponds to an Acceptable performance class and a performance class score $PCS_{B.3}$ = 40 (Figure 46).

Table 83. Example of B.3 evaluation.

Indicator	**Wind**	**Earthquake**	**Tsunami**	**Fire**	**Blast**
B.3.1	40	45	60	95	95
B.3.2	60	75	100	95	95
min(B.3.1+B.3.2)	100	—	—	—	—
B.3.3	65				
B.3	= (0.35 · 40 + 0.35 · 60) + 0.3 · 65 = 54.5				
Performance class	*Acceptable*				
$PCS_{B.3}$	40				

Source: JRC.

4.7 Ensuring occupant health, comfort and wellbeing (B.4)

4.7.1 Description and assessment

The Ensuring occupant health, comfort and wellbeing KPI (B.4) looks to evaluate the extent to which the project design provides a healthy environment which supports and promotes physical, social and mental health, and in which the users can easily cater to their needs, have a meaningful experience and thrive.

Four main areas of project design that have been linked to occupant health, comfort and wellbeing are considered within B.4:

— *Indoor acoustic environment (B.4.1)*: extent to which harmful or intrusive noises are prevented and the users are provided with a healthy and productive acoustic environment.

— *Lighting environment (B.4.2)*: extent to which natural and artificial lighting systems support health, wellbeing, orientation, safety and the ability to conduct tasks, for all users.

— *Thermal comfort (B.4.3)*: extent to which the design caters for the thermal comfort of diverse users.

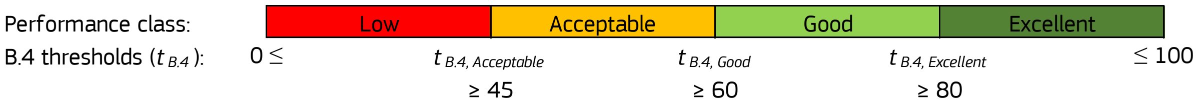
— *Promotion of physical movement (B.4.4)*: extent to which opportunities for physical movement are integrated into the project.

B.4 score is evaluated according to Equation (159).

$$B.4 = \sum_{j=1}^{4}\left(w_{B.4.j} \cdot B.4.j\right) \Big/ \sum_{j=1}^{4}\left(w_{B.4.j}\right) = 0.25 \cdot (B.4.1 + B.4.2 + B.4.3 + B.4.4) \leq 100 \qquad (159)$$

Each indicator is evaluated with a score between 0-100 and a corresponding indicative performance class (indicator class is provided just to guide users but not used further in the evaluation of KPIs and dimensions), according to adherence with best-practice design guidance, and beyond best-practice standards and guidance that are typically voluntary. The performance class of the B.4 KPI is assessed according to the thresholds in Figure 64.

Figure 64. B.4 performance classes and thresholds.



Source: JRC.

The KPI and its indicators are designed to be implemented at all project scales, types and main uses (Table 48). The assessment of B.4.1, B.4.2, B.4.3 and B.4.4 is affected by the project scale and type.

When a project, classified into the neighbourhood or urban scale, involves several buildings with distinct design characteristics, thus likely leading to different indicator scores for each of them, the evaluation of the indicators shall be carried out by identifying representative samples of buildings with similar design features. For each of these representative building designs, a separate assessment should be performed. The overall score per indicator is then estimated as a weighted average of the separate assessment scores, with the weights obtained from the relative occurrence of each building design.

For renovation projects, the assessment focuses on the specific aspects of the building and spaces that are affected by the proposed renovation works. However, when indicators and/or metrics address an aspect that has not been altered by the renovation, their evaluation should consider the as-built state (i.e. condition before the intervention is set), as this affects the user health, comfort and wellbeing.

The definition of the B.4 KPI and indicators draws heavily upon of the following key standards, certification schemes and guidance documents: CEN (2021b), IWBI (2020), Fitwel (2020), PAS 6463 (BSI, 2022) and Level(s) (Dodd et al., 2021e, f, g).

EN 17210 (CEN, 2021b) is a European standard adopted by the 34 member countries of the European Committee for Standardisation. The main goal of the standard is to contribute to the implementation of the UN Convention on the Rights of Persons with Disabilities in Europe (COM, 2010). EN 17210 (CEN, 2021b) is a performance standard, and aims to provide the basic, minimum functional requirements and recommendations for the design, construction, refurbishment or adaptation, and maintenance of an accessible and usable built environment, including guidance on outdoor pedestrian and urban areas. Although adherence to this standard is mandatory for publicly funded projects in the EU, the scope of NEB extends its use to privately funded projects. Hence, in many of the indicators within B4, EN 17210 is adopted in the definition of the Acceptable performance class.

As a performance standard, EN 17210 provides design direction without limiting to a prescribed metric, which allows for greater flexibility for implementation across countries and without the risk of conflicting with other existing standards. National standards or regulations may be used to determine the technical performance criteria and specifications to fulfil the functional requirements of EN 17210. However, if national standards or regulations standards are insufficient or lacking, the supplementary technical reports TR 17621 (CEN, 2021c) and TR 17622 (CEN, 2021a), provide the necessary information on how to meet the performance standard. As the technical performance criteria set out in these reports are typically more stringent than those in most national standards and regulations, compliance with TR 17621 and TR 17622 is adopted in the definition of the Good performance class in many of the indicators within B.4.

WELL v2 (IWBI, 2020) and Fitwel (2020) are two of the few certification schemes that focus on the health and wellbeing of occupants and users. Both define design features and metrics for achieving specific health and wellbeing goals in projects. A number of design features and associated metrics in WELL and Fitwel are adopted in the definition of the Good and Excellent performance classes in the indicators within B.4. Although WELL requires an on-site assessment as part of its certification process, only those metrics that can be evaluated at the design stage are considered here. Both the WELL and Fitwel standards are continuously updated as new research findings are published. Hence, in the evaluation of B.4, the latest versions of these standards should be used.

PAS 6463 (BSI, 2022) provides guidance on the design of the built environment to include the needs of people who experience sensory/neurological processing differences. Such needs are often excluded from existing design standards, and are not fully incorporated in current certification schemes. PAS 6463 aims to help with the design, creation or management of intuitive environments which readily accommodate the neurological variations in the way people perceive, process and organise sensory information, received through hearing, sight, touch, smell or movement. The guidance provided by PAS 6463 contributes to the definition of the Good and Excellent classes for indicators within B.4.

The evaluation of the indicators in B.4 is conducted by the design team, comprising architects, structural engineers and service engineers, potentially seeking the advice of product manufacturers, and main and specialist contractors. The assessment requires the following information to be identified and collected:

— Standards, guidelines and certification scheme documents, as well as any national standards relevant to acoustic, lighting, thermal comfort and active design.

— Information of the project location and orientation, and relevant maps of pedestrian areas, cycle lanes and public transportation.

— Project design plans, architectural and structural design drawings, service plans, (especially lighting and HVAC).

— Plans for the use of different areas of the project, with identification of regularly occupied individual and multi-occupant spaces.

— Information on the type of users and their needs.

— Information of sources of noise outside and inside the building and estimates of their values.

— Characteristics of internal finishes (ceiling, walls, flooring), and manufacturer information regarding the reflectance and acoustic performance of materials.

— Manufacturer information regarding acoustic insulation of the envelope and façades, and regarding any mechanical systems (HVAC) used for cooling or heating.

— Information on provided amenities, with particular focus on those related to physical activity.

4.7.2 Indoor acoustic environment (B.4.1)

The Indoor acoustic environment indicator (B.4.1) evaluates the extent to which the project design provides users with a healthy and productive acoustic environment, that is void of harmful or intrusive noise, and which supports speech intelligibility. The evaluation of the indicator score is summarised in Table 84, based on compliance with best practice standards and beyond best-practice guidance that specifically address users with diverse abilities. The indicator score cannot exceed 100. On some occasions, next to the metrics of the indicator, a “non-applicable” option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects.

Figure 65 shows indicator thresholds adopted to associate the indicator score to an indicator performance class. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Table 84. B.4.1 score.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project does not comply with EN 17210 (CEN, 2021b) Section 15.2 Acoustics	B.4.1 = 0. No further points to be added.	
The project complies with EN 17210 Section 15.2 Acoustics.	*Check next metrics.*	
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with acoustic design criteria that are less stringent than TR 17621 (CEN, 2021c).	+20	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent acoustic design criteria.	+40	
The project also complies with the following WELL v2 (IWBI, 2020) features (multiple selections allowed):		
S03 Sound barriers – Part 1: Design for sound isolation at walls and doors	+10	
S04 Reverberation time-option 1	+10	☐

S05 Sound reducing surfaces	+10	☐
S06 Minimum background sound - Part 1	+10	☐
S07 Impact noise management – Part 1	+10	
S08 Enhanced audio devices – Part 1	+10	
The project also complies with the following criteria from PAS 6463 (BSI, 2022) (multiple selections allowed):		
Acoustic zoning is used to allow people to make a gradual transition from the quietest to the noisiest space within a building	+5	
Quieter spaces, including enclosed quiet rooms and semi-enclosed quieter zones, are provided as options to escape if a noisy over-stimulating environment becomes intolerable	+5	
Individual control for noise is provided through (a) the ability to switch extractor fans on or off, and (b) the option to close windows or ventilator panels when noise comes from the street	+5	☐
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

Figure 65. B.4.1 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.4.1 thresholds ($t_{B.4.1}$):	0 ≤		$t_{B.4.1, Acceptable}$ ≥ 20		$t_{B.4.1, Good}$ ≥ 50		$t_{B.4.1, Excellent}$ ≥ 80		≤ 100

Source: JRC.

Excessive noise seriously harms human health and interferes with people's daily activities at school, at work, at home and during leisure time. Many health consequences of exposure to excessive noise have been identified, such as sleep disturbance, cardiovascular and psychophysiological issues, performance reduction and changes in social behaviour (WHO, 2011). The importance of protecting citizens from noise is recognised in European policy, with Directive (2002) on the assessment and management of environmental noise. Typically, noise problems that affect health and wellbeing within an indoor space result from (Dodd et al., 2021g; IWBI, 2020):

— Too much noise outside the building entering the space (typically this includes noise from air traffic, rail, road traffic congestion, industrial works and processes, construction, public works etc.).

— Too much noise from activities adjacent to the space, including:

  - Airborne noise (generated in the air and transmitted by air, such as sounds from speech, radio, television etc. in adjacent spaces or buildings).

  - Impact noise (generated by physical interaction with the building structure causing it to vibrate. Examples include footfall, exercise or mechanical equipment vibration that can create uncomfortable environments for occupants located nearby).

— Too much noise from service equipment or occupants in the space itself (e.g. sound from HVAC equipment, appliances and other occupants).

— Lack of sound control and inappropriate reverberation times (see later definition) in the space.

Even when not at harmful levels, too much noise may affect speech intelligibility and can be distracting, reducing functionality, productivity and enjoyment of spaces. An acoustic environment where all users can distinguish essential sounds (primary sounds) from general background noise (ambient noise other than primary sounds) is essential. In particular, people with hearing and cognitive impairments can have difficulties in making out sounds and words in noisy environments (CEN, 2021b).

Evaluation of the appropriateness of an indoor acoustic environment depends on the use, occupancy type and level of the space being designed, as well as a number of interacting design features, including sound isolation provided by façades and partitioning elements (e.g. walls and floors), surface shapes and finishing materials, indoor acoustic design and noise and vibration mitigation of service equipment. EN 17210 (CEN, 2021b) sets out performance objectives for indoor acoustic environments considering all these aspects, and specifically considers speech transmission and intelligibility. This standard is considered best-practice for acoustic environment design. Non-compliance with this performance standard results in an indicator score of 0 (indicative of Low performance in Figure 65).

An Acceptable performance class is based (at a minimum) on compliance with EN 17210 using national guidelines. A performance class exceeding the Acceptable can be achieved by demonstrating compliance with the EN 17210 performance criteria, using the material and element specifications as well as threshold values of acoustic environment metrics as defined in TR 17621 (CEN, 2021c) (or alternative national guidance that provides equal or more stringent criteria than TR 17621 for all aspects of the acoustic design).

Higher indicator scores can also be achieved by implementing selected relevant guidance and thresholds in WELL v2 (IWBI, 2020) and PAS 6463 (BSI, 2022) that ensure acoustic comfort for people with diverse abilities and neurodiversity. These include more stringent values for background noise, the use of dedicated artificial sound to uniformly increase speech privacy between occupied spaces (i.e. sound masking), and provision of enhanced user control over noise.

To characterise the level of noise from external sources, the Level(s) approach (Dodd et al., 2021g) for the evaluation of the noise levels at the façade of a building may be used. Level(s) state that the yearly average noise level (with a daily penalty distribution) or the maximum noise level can be estimated according to the calculation method described in Annex II of Directive (2002).

Background noise levels combine noise penetration from outside and inside sources of noise. Several acoustic software models exist for the prediction of indoor noise levels. Alternatively, predictions may be based on the sound insulation properties of the façades and reverberation times of the receiving rooms using a building element approach (e.g. ISO 12354-3, ISO, 2017a).

Thresholds of background noise levels are defined differently in the reference standards for different occupancy and uses of the space. Hence, at design stage, it is necessary to map the likely uses of the different spaces within a project. The WELL v2 (IWBI, 2020) certification system proposes the following five acoustic categories for spaces:

— *Loud zone*: includes areas intended for loud equipment or activities (e.g. mechanical rooms, AV/IT closets, kitchens, fitness rooms, social spaces, recreational rooms, music rooms).

— *Quiet zone*: includes areas intended for concentration, wellness, rest, study and/or privacy (e.g. restorative spaces, lactation rooms, nap rooms).

— *Mixed zone*: includes areas intended for learning, collaboration and/or presentation (e.g. auditoriums, classrooms, breakout spaces).

— *Circulation zone*: includes occupiable areas not intended for regular occupancy (e.g. hallways, egress, atria, stairs, lobbies)

— *Not applicable zones*: includes other areas without significant sources of sound (e.g. storage rooms, janitor rooms, coat closets) that are not regularly occupied.

Key parameters adopted by the referenced standards and guidelines for determining the acoustic environment and speech intelligibility of a space, are the reverberation time (T) and speech transmission index (STI).

The reverberation time (T) is the time, in seconds (sec), that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped. The reverberation time is strongly dependent on the frequency of the sound and the absorptive properties of the materials in the space assessed. As stated in Level(s), the chosen frequency range for the reverberation time is often in 1/1 octave bands of 125 or 250Hz to 4kHz for rooms where people work, rest or stay for more than a few minutes (Dodd et al., 2021g). For rooms where people simply pass through, like hallways and staircases, the frequency range in octave bands is often 500Hz to 2kHz (Dodd et al., 2021g). The sound absorption of the room can be characterised by the equivalent absorbing area (A_{eq}) of the room. The reverberation time (T), and the equivalent sound absorption area (A_{eq}), can be estimated using EN 12354-6 (CEN, 2003), based on volume and sound absorption data. The latter can be estimated from material specifications, or from standards and guidelines (e.g. absorption coefficients for common surfaces in buildings and for objects are provided in Annex B and C of EN 12354-6, respectively).

The speech transmission index (STI) is described in IEC 60268-16 (IEC, 2020) and quantifies the transmission of the speech signal between a speaker and a listener. This can be evaluated using various available acoustic environment planning software.

Threshold (or ranges of) values for T and STI are included in national guidance in accordance with the use and occupancy type and level of the space being assessed. Such threshold values may be used to achieve the performance levels required by EN 17210 (CEN, 2021b). Alternatively, the typically more demanding threshold values set out in TR 17621 (CEN, 2021c) and WELL v2 (IWBI, 2020) may be used to increase the acoustic environment indicator score.

4.7.3 Lighting environment (B.4.2)

The Lighting environment indicator (B.4.2) evaluates the extent to which the project adopts a natural and artificial lighting system that supports health, wellbeing, orientation, safety and the ability to conduct tasks, for all users.

The evaluation of the indicator score is summarised in Table 85, based on compliance with best practice standards and beyond best-practice guidance that specifically address users with diverse abilities. The indicator score cannot exceed 100. On some occasions, next to the metrics of the indicator, a "non-applicable" option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects.

Figure 66 shows indicator thresholds adopted to associate the indicator score to an indicator performance class. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Table 85. B.4.2 score.

Metric	Score	Non-applicable[1]
Select single value below:		
The project does not comply with the EN 17210 (CEN, 2021b) sections listed below.	B.4.2 = 0. No further points to be added.	
The project complies with the following EN 17210 sections:[2]	*Check next metrics.*	
6.3.4 Wayfinding - visual contrast		
9.1.8 Entrances		
9.2.14 Lighting in corridors and passageways		☐
10.1.11 Lighting of ramps and landings		☐
10.2.8 Lighting of steps and stairs		☐
10.4.9 Lighting of lifts		☐
11.1.9 Service counters for information, ticketing and reception		☐
15.1 Lighting		
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with lighting design criteria that are less stringent than TR 17621 (CEN, 2021c).	+20	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent lighting design criteria	+40	
The project also complies with the following WELL v2 (IWBI, 2020) features (multiple selections allowed):		
L01 Light exposure	+5	
L02 Visual lighting design	+5	
L04 Electric light glare control	+5	
L05 Daylight design strategies with Tier 1 **or** Tier 2 requirements	+5 **or** +7.5	
L06 Daylight simulation with Tier 1 **or** Tier 2 requirements	+5 **or** +7.5	
L07 Visual balance	+5	
L08 Electric light quality	+5	
L09 Occupant lighting control: Part 1 with Tier 1 requirements & Part 2 (2) **or** Part 1 with Tier 2 requirements & Part 2 (2)	+5 **or** +7.5	
The project also complies with the following criteria from PAS 6463 (BSI, 2022):		
Buzzing or humming noises from lighting is avoided. These may occur with LED luminaires or when lighting is operating at a dimmed level of intensity. In areas used for relaxation or rest, lighting correlated colour temperature (CCT) is adjustable or 2700-3000K.	+5	
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
[2] If the section of EN 17210 does not apply to the project (i.e. non-applicable is selected), then as long as all other stated sections are complied with, then the project is deemed to be in compliance with EN 17210.

Source: JRC.

Figure 66. B.4.2 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
B.4.2 thresholds ($t_{B.4.2}$):	0 ≤	$t_{B.4.2, Acceptable} \geq 20$	$t_{B.4.2, Good} \geq 50$	$t_{B.4.2, Excellent} \geq 80$	≤ 100

Source: JRC.

Key factors to provide visual conditions to support visual tasks, orientation and safety, include: level of illumination of horizontal and vertical surfaces, limitation of glare from a light source or reflections, uniformity and luminance distribution, direction of lighting and shading, and colour. EN 17210 (CEN, 2021b) sets out performance objectives for lighting related criteria in several sections of the standard, covering both indoor and external lighting. These relate to how lighting contributes to wayfinding, safety and the lighting needs of different users to conduct visual tasks. Approaches to the reduction of glare are provided, and the standard promotes users being able to adjust lighting environments. Moreover, EN 17210 promotes the consultation with users to identify their needs for the lighting environment.

The EN 17210 standard is considered best-practice currently for lighting environment design. Non-compliance with this performance standard results in an indicator score of 0 (indicative of Low performance in Figure 66).

An Acceptable performance class is based (at a minimum) on compliance with EN 17210 using national guidelines. A performance class exceeding Acceptable can be achieved by demonstrating compliance with the EN 17210 using metrics as defined in TR 17621 (CEN, 2021c) (or alternative national that provides equal or more stringent criteria than TR 17621 for all aspects of the lighting environment design).

Higher indicator scores can also be achieved by implementing selected relevant guidance and thresholds in WELL v2 (IWBI, 2020), PAS 6463 (BSI, 2022) and Fitwel (2020). These consider lighting environments for people with diverse abilities and neurodiversity. They include even more stringent values for minimum light levels provided for various tasks, but specifically aim to promote the use of lighting systems (natural and artificial) that contribute to physical and mental wellbeing.

For compliance with EN 17210 (CEN, 2021b), TR 17621 (CEN, 2021c) calls upon a number of other standards. In particular, EN 13201-2 (CEN, 2015a) — Road Lighting — is called upon for outdoor lighting. This standard defines lighting performance objectives on the basis of lighting classes, which are based on the type of vehicle and road/pathway type. Highlighted lighting classes include class P and HS which are for pedestrians and pedal cyclists on footways and cycleways etc. The SC class is an additional class for use in high crime areas, where public lighting is needed for the identification of people. Calculation approaches for meeting the performance objectives are provided in EN 13201-3 (CEN, 2015b).

A space is considered to provide adequate daylight if a target illuminance ($\bar{E}$) level is achieved across a fraction of the reference plane within a space for at least half of the daylight hours. The reference plane of the space is located 0.85 m above the floor, unless otherwise specified (EN 17037, CEN, 2021e). The adequacy of daylight provision to an interior space can be calculated as per EN 17037 section 5.1.3, using a method based on daylight factors (Method 1), or through simulation (Method 2). Annex A in EN 17037, provides the minimum target illuminances (and corresponding daylight factors) for spaces with different uses, that can be adopted to determine the appropriateness of the lighting. It is noted that many standards and guidelines adopt daylight factors as proxies for illuminance (e.g. Active House Alliance, 2020). However, calculating daylight factors (Method 1) requires complex repetition of calculations, and thus they are generally undertaken using a professional lighting design software.

For indoor artificial lighting TR 17621 (CEN, 2021c) calls upon EN 12464-1 (CEN, 2021g) for the lighting of workplaces, which specifies requirements for lighting solutions for most indoor workplaces and their associated areas in terms of quantity and quality of illumination. This standard defines minimum illuminance levels ($\bar{E}_{min}$) and uniformity of illuminance (U_o) for different space uses. It also provides guidance on ranges of surface reflectance to achieve good illuminance and contribute to room brightness. Again, professional lighting calculation software may be used for the illuminance calculation.

Glare is a negative sensation caused by bright areas with sufficiently greater luminance than the luminance to which the eyes are adapted, producing annoyance, discomfort or loss in visual performance and visibility (EN 17037, CEN, 2021e). The perception of glare is dependent on the luminance distribution in the field of view and is therefore strongly dependent on the spatial position and the line of sight of the occupant. A simplified approach to consider glare is the daylight glare probability (DGP) presented in EN 14501 (CEN, 2021d). DGP is used to assess protection from daylight glare in spaces where the activities are comparable to reading, writing or using display devices, and where the occupants are not able to choose position and viewing direction. For determination of glare from artificial lighting instead, the methodology defined in CIE 117 (CIE, 1995) may be used. This uses the unified glare rating (UGR) as a measure of potential discomfort glare experienced by an occupant in interior lighting spaces.

4.7.4 Thermal comfort (B.4.3)

The thermal comfort indicator (B.4.3) evaluates the extent to which the design caters for the thermal comfort of diverse users. The evaluation of the indicator score is summarised in Table 86, based on compliance with the best-practice standard WELL v2 (IWBI, 2020) that specifically accounts for users with diverse abilities. The indicator score cannot exceed 100. On some occasions, next to the metrics of the indicator, a “non-applicable” option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects. Figure 67 shows indicator thresholds adopted to associate the indicator score to an indicator performance class. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Measuring thermal comfort in buildings typically involves assessing people’s levels of comfort relative to several parameters describing the environment (e.g. air temperature, relative humidity and air velocity). These in turn depend on project design features such as site location and project orientation with respect to the sun and prevailing winds, building envelope materials and design, use of natural ventilation, use of shading, and use of heating and cooling systems, amongst others. The feeling of comfort, however, is subjective, and depends on people’s physiology, the activity they are doing and what they are wearing. There is therefore no one-fits-all solution, and the aim in designing for thermal comfort is not to ensure thermal comfort for all, but rather to provide a baseline satisfaction for the largest number of people while providing people some level of thermal control to adjust their thermal comfort level where possible. It is also important to note the connection between provision of indoor thermal comfort and energy use. Over 80% of the energy used in EU households in 2022 was for heating, cooling and hot water (Eurostat, 2024). Hence, energy consumption must be considered in addition to the provision of thermal comfort in design (see 3.4 in Sustainability chapter).

One of the most used parameters to evaluate thermal comfort is the predicted mean vote (PMVo), which was developed by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE). The parameter uses the fact that human body temperature is maintained at optimum levels (37 degrees) through heat exchange between the human body and the environment by convection, radiation, and evaporation (ASHRAE, 2023). PMVo relates the imbalance between the actual heat flow from the body into a given environment and the heat flow required for optimum comfort. PMVo is evaluated through a set of semi-empirical equations, and is supposed to represent the mean response of a large group of people according to the ASHRAE 55 thermal sensation scale (ASHRAE, 2023). The ASHRAE 55 scale has seven comfort ratings, ranging from hot (PMVo = 3) to cold (PMVo = –3), with a comfortable environment deemed to be one where PMVo values lie between –1 and 1. PMVo is one of the parameters adopted in WELL v2 (IWBI, 2020) T01 criterion, which in turn provides the threshold for the Acceptable performance class in B.4.3.

Table 86. B.4.3 score.

Metric	**Score**
Select single value below:	
The project does not comply with any of the following WELL v2 (IWBI, 2020) criteria.	B.4.3 = 0. No further points to be added.
The project complies with the following WELL v2 criteria	*Check next metrics.*
WELL v2 criteria (multiple selections allowed):	
T01 Thermal performance – Part 1	+40
T03 Thermal zoning	+15
T05 Radiant thermal comfort	+15
T07 Humidity control	+15
T08 Enhanced operable windows	+15
T09 Outdoor thermal comfort – Part 1	+15
Indicator score = Σ(metric scores)	**≤ 100**

Source: JRC.

Figure 67. B.4.3 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent	
B.4.3 thresholds ($t_{B.4.3}$):	$0 \leq$	$t_{B.4.3, Acceptable} \geq 20$	$t_{B.4.3, Good} \geq 50$	$t_{B.4.3, Excellent} \geq 80$		≤ 100

Source: JRC.

4.7.5 Promotion of physical movement (B.4.4)

The Promotion of physical movement indicator (B.4.4) evaluates the extent to which the design encourages physical movement where there are such opportunities. The evaluation of the indicator score is summarised in Table 87, based on guidance provided as part of the WELL v2 Movement (IWBI, 2020), which aims to promote movement, foster physical activity and active living and discourage sedentary behaviour, by creating and enhancing opportunities through living spaces where we spend our lives. WELL v2 (IWBI, 2020) also specifically addresses users with diverse abilities. The indicator score cannot exceed 100. On some occasions, next to the metrics of the indicator, a "non-applicable" option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects. Figure 68 shows indicator thresholds adopted to associate the indicator score to an indicator performance class. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

The design requirements of WELL v2 (IWBI, 2020) and Fitwel (2020) included in B.4.4 promote circulation in the inside and outside of buildings, and provide opportunities for reducing sedentary behaviour through appropriate furnishings, also promoting better posture.

Table 87. B.4.4 score.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project does not comply with any of the following WELL v2 (IWBI, 2020) criteria (i.e. V02–V08).	B.4.4 = 0. No further points to be added.	
The project complies with the following WELL v2 criteria (i.e. V02–V08).	*Check next metrics.*	
WELL v2 criteria V02–V08 (multiple selections allowed):		
V02 Ergonomic workstation design – Parts 1-4	+15	☐
V03 circulation network[2]	+15	
V04 Facilities for active occupants	+15	
V05 Site planning and selection	+15	
V07 Active furnishings with Tier 1 **or** Tier 2 requirements	+15 **or** +20	☐
V08 Physical activity spaces and equipment (both Parts 1 and 2)	+20	
The project also complies with the following criterion:		
Fitwel 8.7 Multi-purpose room (Fitwel 2020)	+15	
Indicator score = Σ(metric scores)	**≤ 100**	

1 If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

2 Effort should be made to provide stairs as close as possible to the lifts, to reduce separation and provide a similar journey for people using the stairs and people using the lifts. Lifts should be easy to locate with appropriate wayfinding and signage. It should be ensured that any enhanced feature of the stair, such as music, artwork or game, does not create a safety hazard, disturbance or distraction to users who may be negatively impacted.

Source: JRC.

Figure 68. B.4.4 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent	
B.4.4 thresholds ($t_{B.4.4}$):	$0 \leq$	$t_{B.4.4, Acceptable} \geq 20$	$t_{B.4.4, Good} \geq 50$	$t_{B.4.4, Excellent} \geq 80$		≤ 100

Source: JRC.

4.7.6 Example (B.4)

A four-storey residential building is to be designed (newbuild project type) in an urban area of Lisbon, Portugal. The assessment is carried out at the building scale and no listed cultural heritage is affected by the project. The building has a plan of 23.5 m by 23.5 m. The building has a symmetrical and identical repeated floor plan on each floor, with each façade made up of 5 rooms (i.e. 16 perimeter rooms, as corner rooms have two façades). The building is composed of a reinforced concrete frame with façades made of double brickwork with air cavity. A central lift and stairwell are located at the centre of the building plan.

External sources of noise mainly include road traffic. On average, 10 000 vehicles per day use the residential roads around the building, with 10% being heavy vehicles. 15% of the daytime traffic is on average using the roads at night. The A-weighted long-term average sound pressure levels for the day, night and evening are calculated in octave bands according to Annex II of Directive (2002). The estimated outdoor free field sound pressure level is calculated as 50 dB. The sound pressure level 2 m from the façade of the building is found to be 53 dB.

The formulation in equation E.2 of ISO 12354-3 (ISO, 2017a) is used to evaluate the indoor sound pressure level, standardised to 0.5 sec reverberation time. This value is calculated from the standardised level difference of the façade as per equation 4 of ISO 12354-3, which in turn is evaluated from estimates of the sound reduction index of the façade and the receiving room size. The building is composed of a reinforced concrete frame with façades made of double brickwork with air cavity, with surface mass of 400 kg/m^2. A typical room along the centre of the façade of the building has a volume of 50 m^3, a façade of 11.3 m^2, and contains a 4.5 m^2 window with double glazing that is partially openable, with an acoustically treated air inlet located above the window. Sound reduction indices for each façade element are adopted from ISO 12354-3 and the calculation procedure shown in example G.1 of ISO 12354-3 is followed. This results in a standardised level difference of the façade of 29 dB and hence an indoor sound pressure level of 24 dB (i.e. = 53 – 29). The room is equipped with a mechanical ventilation system that produces an additional 10 dB of background noise, resulting in a total of 34 dB background noise. This is considered low and meets the criteria of TR 17621 (CEN, 2021c). It also lies below the threshold for maximum background noise for dwellings stated in WELL v2 (IWBI, 2020).

The reverberation time is calculated as per equation 5 of EN 12354-6 (CEN, 2003). Considering the 50 m^3 room used in the above example, it has usable dimensions (length, width, height) of 4.42 m, 4.70 m and 2.40 m. The floors and ceilings are made of concrete and the walls of plastered brick. There is one window (as previously described) and a door of height and width equal to 2.04 m and 0.93 m, respectively. The floor has a soft layer with a depth greater than 10 mm. The values for the absorption of materials are obtained from Annex B of EN 12354-6 and the total equivalent absorption area is calculated as per section 4.3 in EN 12354-6, considering an empty room. This is shown in Table 88 for the frequency of 1000 Hz, resulting in a reverberation time of 1 sec. This does not meet the requirements in WELL v2 S04 (IWBI, 2020). However, the STI is also calculated using an acoustic environment planning software, resulting in compliance with the values provided in TR 17621 (CEN, 2021c).

Table 88. Calculation of equivalent absorption area for a typical room.

Element	**Area (m^2) [1]**	**Absorption coefficient [2]**	**[1] x [2] (m^2)**
Ceiling	20.77	0.02	0.415
Floor	20.77	0.30	6.231
Walls minus door and window	37.38	0.02	0.748
Door	1.89	0.08	0.151
Window	4.50	0.04	0.180
Equivalent absorption area (A_{eq}) =			**7.725**

Source: JRC.

The calculation is repeated for all rooms and spaces in the building plan and compliance with EN 17210 (CEN, 2021b) using the criteria of TR 17621 (CEN, 2021c) is demonstrated. Interior walls meet the sound transmission class values in WELL v2 (IWBI, 2020) S03 Part 1. The noise reduction coefficient (NRC) rating (WELL v2 S05) is calculated as the arithmetic average of the absorption coefficients at 250, 500, 1000, and 2000 Hz octave bands (obtained for the used materials from Annex B of EN 12354-6, CEN, 2003), rounded to the nearest multiple of 0.05. For the ceilings of the typical room, which is made of concrete, NRC is 0.014 (which rounded to the nearest non-zero 0.05, is 0.05). Although, this falls below any of the recommended values for WELL v2 (IWBI, 2020) S05, as the building is residential, composed of dwelling units, WELL v2 (IWBI, 2020) S04, S05 and S06 do not apply, and these criteria are given full scores. An approximate impact insulation class (IIC) rating of 75 is obtained from Warnock (1999) for concrete floors with carpet and underlay, and is seen to comply with the requirements of WELL v2 Impact noise management – Part 1 (IWBI, 2020). No enhanced audio devices are used in the building (hence, no compliance with the WELL v2 (IWBI, 2020) S08 requirements). Finally, individual control for noise is provided throughout the building by allowing users to switch extractor fans on or off and close windows or ventilator panels when noise comes from the street.

B.4.1 score is evaluated in Table 89 (corresponding to Excellent performance for this indicator).

Table 89. Example of B.4.1 evaluation.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project does not comply with EN 17210 (CEN, 2021b) Section 15.2 Acoustics	x	
The project complies with EN 17210 Section 15.2 Acoustics.	√ *Check next metrics.*	
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with acoustic design criteria that are less stringent than TR 17621 (CEN, 2021c).	0	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent acoustic design criteria.	+40	
The project also complies with the following WELL v2 (IWBI, 2020) features (multiple selections allowed):		
S03 Sound barriers – Part 1: Design for sound isolation at walls and doors	+10	
S04 Reverberation time-option 1	+10	☒
S05 Sound reducing surfaces	+10	☒
S06 Minimum background sound - Part 1	+10	☒
S07 Impact noise management – Part 1	+10	
S08 Enhanced audio devices – Part 1	0	
The project also complies with the following criteria from PAS 6463 (BSI, 2022) (multiple selections allowed):		
Acoustic zoning is used to allow people to make a gradual transition from the quietest to the noisiest space within a building	0	
Quieter spaces, including enclosed quiet rooms and semi-enclosed quieter zones, are provided as options to escape if a noisy over-stimulating environment becomes intolerable	0	
Individual control for noise is provided through (a) the ability to switch extractor fans on or off, and (b) the option to close windows or ventilator panels when noise comes from the street	+5	☐
Indicator score = Σ(metric scores)	**95**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

Source: JRC.

The adequacy of the lighting environment is checked with respect to EN 17210 clause 15.1 Lighting (CEN, 2021b) for the typical 50 m^3 room. The 4.5 m^2 window for this specific room is south-facing and is equipped with blinds that have an electric control. The room is used as a bedroom with a home office space, and equipped with 8 LED lights with colour temperature of 2000 k, spaced in a symmetrical grid evenly across the ceiling. The lights are dimmable, make no noise when dimmed and extra light fixtures are available, meeting the WELL v2 L09 Occupant lighting control criteria – Parts 1 and 2 (IWBI, 2020), as well as PAS 6463 (BSI, 2022). The reflectance of the white painted concrete ceiling, brick walls and carpeted floor are 0.6, 0.3 and 0.2, respectively. These are close but outside the recommended ranges specified in EN 12464-1 (CEN, 2021g).

Considering the room dimensions, a grid of 0.5 m is used for the daylight and artificial illuminance calculation. A lighting calculation software is adopted to calculate the daylight factor for the grid and the illuminance due to artificial light for this grid, considering lighting positions and surface reflectance. The adopted tool used ray tracing to perform all lighting calculations.

Daylight factors ranging between 4.3% and 4.9% are calculated across the room. The target daylight illuminance is obtained from EN 17037 table A.2 (CEN, 2021e) as 750 lx, which according to EN 17037 table A.3 for Lisbon requires the daylight factor higher than 4.1%. As all values of daylight factor exceed this minimum value, the illuminance is deemed adequate according to TR 17621 (CEN, 2021c). WELL v2 L01 Light exposure (IWBI, 2020) requires a minimum illuminance of 205 lx over 30% of the floor area for 50% of the daylit hours of the year. This is deemed to be satisfied, as the 16 rooms that run along the façade of the building have a floor area of 315 m^2 (i.e. 4.2 m · 4.7 m · 16) and make up 57% of the area of each floor. Hence,

Hence, more than 30% of the regularly occupied rooms are within a 6 m distance to envelope glazing at each floor. Moreover, the envelope glazing is equal to 90 m^2 (4.5 $m^2 \cdot 5 \cdot 4$) which corresponds to 16% of the regularly occupied floor area (552 m^2 per floor), which in turn exceeds the 7% threshold set in WELL v2 (IWBI, 2020). These values satisfy WELL v2 L01 Options 1-3, L05 Part 1 Tier 1, and L06 Tier 1.

EN 12464-1, clause 7 (CEN, 2021g) provides minimum requirements for the maintained illuminance ($\bar{E}_m$) and minimum illuminance uniformity (U_o) depending on the tasks and/or activities being performed in the space. The following minimum values are obtained from Clause 7.3 table 34 Ref. No. 34.2 Writing, typing, reading, data processing: $\bar{E}_m$ = 500 lx, U = 0.6. As the room may be used by people who have a below normal visual capacity, and who will work in the space for long periods of time, an enhanced minimum $\bar{E}_m$ of 1000 lx is required. The provided artificial light provides illuminance in the range 1300–1500 lx, and the lighting uniformity is 0.8. The lighting system therefore meets the lighting provision requirements of TR 17621 (CEN, 2021c). The WELL v2 L07 minimum uniformity threshold is exceeded (IWBI, 2020), a lighting automation system is not used, and horizontal and vertical luminance contrast ratios are no more than 10:1 between adjacent independently controlled zones, meaning that this WELL v2 (IWBI, 2020) criterion is satisfied.

The blinds used on the window have a low light transmittance and meet the criteria of Class 3 performance according to table E.3 in EN 14501 (CEN, 2021d). According to this standard, this has a ‘good effect’ on glare control, night privacy, visual contact with the outside and daylight utilisation, with no light perceived at incident light levels higher than or equal to 30 000 lx. The daylight glare probability (DGP) is calculated according to EN 17037 (CEN, 2021e) to be between 0.35 and 0.40, which according to table E.1 in EN 14501 (CEN, 2021d) results in glare being perceived but being mostly not disturbing.

For the artificial lighting, the unified glare rating (UGR) tabular method detailed in CIE 117 (CIE, 1995) and in CIE 190 (CIE, 2010) is adopted. UGR is found equal to 17, which is below the maximum limit of 19 stated in table 34 of section 7.3 (CIE, 2010). However, this value is higher than the maximum value of 16 specified in WELL v2 L04 criterion (IWBI, 2020). The colour rendering quality of the lighting also does not meet the criteria of WELL v2 L08 criterion.

The calculation is repeated for each room in the building, considering their specific use, natural and artificial lighting system. It is found that all rooms meet the lighting requirements of EN 17210 (CEN, 2021b) according to the approach and thresholds stated in TR 17621 (CEN, 2021c). Moreover, lighting in the corridors, passageways, lifts, entrances and lifts are similarly found to comply with TR 17621. Lighting in kitchens and bathroom areas comply with the Illuminating Engineering Society (IES) Lighting application standard (IES, 2020), meeting the criteria for WELL v2 L02 criterion for dwelling units (IWBI, 2020).

B.4.2 score is evaluated in Table 90 (corresponding to Good performance for this indicator). For this building, a reduction in glare from artificial lighting could increase the score such that it would reach the Excellent performance class.

Table 90. Example of B.4.2 evaluation.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project does not comply with the EN 17210 (CEN, 2021b) sections listed below.	x	
The project complies with the following EN 17210 sections:[2]	√ *Check next metrics.*	
6.3.4 Wayfinding - visual contrast		
9.1.8 Entrances		
9.2.14 Lighting in corridors and passageways		☐
10.1.11 Lighting of ramps and landings		☐
10.2.8 Lighting of steps and stairs		☐
10.4.9 Lighting of lifts		☐
11.1.9 Service counters for information, ticketing and reception		☒
15.1 Lighting		
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with lighting design criteria that are less stringent than TR 17621 (CEN, 2021c).	0	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent lighting design criteria	+40	
The project also complies with the following WELL v2 (IWBI, 2020) features (multiple selections allowed):		

L01 Light exposure L02 Visual lighting design L04 Electric light glare control L05 Daylight design strategies with Tier 1 **or** Tier 2 requirements L06 Daylight simulation with Tier 1 **or** Tier 2 requirements L07 Visual balance L08 Electric light quality L09 Occupant lighting control: Part 1 with Tier 1 requirements & Part 2 (2) **or** Part 1 with Tier 2 requirements & Part 2 (2)	+5 +5 0 +5 +5 +5 0 +7.5	
The project also complies with the following criteria from PAS 6463 (BSI, 2022):		
Buzzing or humming noises from lighting is avoided. These may occur with LED luminaires or when lighting is operating at a dimmed level of intensity. In areas used for relaxation or rest, lighting correlated colour temperature (CCT) is adjustable or 2700-3000K.	+5	
Indicator score = Σ(metric scores)	**77.5**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.

[2] If the section of EN 17210 does not apply to the project (i.e. non-applicable is selected), then as long as all other stated sections are complied with, then the project is deemed to be in compliance with EN 17210.

Source: JRC.

Thermal comfort is calculated for the typical 50 m^3 room. The room is mechanically ventilated and equipped with central heating.

The first parameter to calculate is the predicted mean vote (PMVo). Assuming limited activity inside the residence, the rate of metabolic energy production (M) is assumed equal to 58.2 Watt/m^2 and the rate of mechanical work (W) is zero. The mean radiant temperature (T_{mr}) is the uniform temperature of an imaginary black enclosure in which radiant heat transfer from a person equals the radiant heat transfer in the actual enclosure. The value of T_{mr} can be calculated from knowledge of the temperature of each surface in a room and the position of a person relative to the surfaces, following the approach in ASHRAE 55 (ASHRAE, 2023). In this example, T_{mr} is estimated equal to 23 ^{0}C. The water vapour pressure equals 1.419 kPa and the user is assumed fully clothed. The speed of air, circulating throughout the building space, is 0.1 m/s. This results in a PMVo of –0.202 (comfortable environment). PMVo is calculated for all spaces in the building, and it is observed that PMVo values between +0.5 and –0.5 exist for more than 90% of the regularly occupied spaces. Hence WELL v2 (IWBI, 2020) T01 – Part 1 is satisfied.

The typical room is equipped with a thermostat which can be used to regulate the temperature. The room forms a thermal zone, as do the other rooms on the floorplan with similar layout and area. The room floor area is less than the 60.4 m^2 limit for thermal zone definitions in WELL v2 T03 criterion (IWBI, 2020).

At least 50% of the regularly occupied project area is heated and cooled with radiant panels, but these do not cover at least half of the wall to which they are attached. Hence, WELL v2 (IWBI, 2020) T05 criterion is satisfied.

The relative humidity in moist air is the ratio of partial vapor pressure to air pressure. The room relative humidity is modelled with computational fluid dynamics (CFD) software, and is found to be 35% for 98% of all business hours of the year. Moreover, the mechanical ventilation system has the capability of maintaining relative humidity between 30% and 45% at all times, by adding or removing moisture from the air. The operable window in the typical room can open to allow greater ventilation, and instructions for the window operation are provided. These conditions meet the criteria of WELL v2 (IWBI, 2020) T07 and T08 criteria.

60% of pedestrian pathways and building entrances are shaded for more than half of daylight hours each day by awnings. An outdoor seating area and children's play area are provided near the building. 50% of their area is shaded by tree canopies. These conditions comply with WELL v2 (IWBI, 2020) T09 – Part 1.

The score of B.4.3 is evaluated in Table 91 (corresponding to Excellent performance for this indicator).

Table 91. Example of B.4.3 evaluation.

Metric	**Score**
Select single value below:	
The project does not comply with any of the following WELL v2 (IWBI, 2020) criteria. The project complies with the following WELL v2 criteria	x √ *Check next metrics.*
WELL v2 criteria (multiple selections allowed):	

T01 Thermal performance – Part 1 T03 Thermal zoning T05 Radiant thermal comfort T07 Humidity control T08 Enhanced operable windows T09 Outdoor thermal comfort – Part 1	+40 +15 +15 +15 +15 +15
Indicator score = Σ(metric scores)	**100**

Source: JRC.

The promotion of physical movement indicator is calculated next, considering the typical 50 m^3 room of the building example. As previously mentioned, the room is used as a bedroom and home office. The latter is equipped with a docking station for a laptop, which includes an external keyboard, mouse, adjustable laptop stand and an external monitor. The workstation can be adjusted by the user to work both in a seated and standing position, and the associated workstation chair is also adjustable in height with an adjustable seat pan and backrest angle. Being a home office, the user is not required to stand for 50% or more of their work hours. These design features are provided for all the home office rooms in the building, hence, they meet the WELL v2 criteria for V02 Ergonomic workstation design – Parts 1-4, and V07 Active Furnishings with Tier 2 requirements (IWBI, 2020).

The residential building has a central staircase that is open to all residents of the building and services all occupiable floors. Each apartment door opens onto the stairwell platform. The staircase is decorated with artwork depicting images of nature, and the staircase has a light level of 200 lx. At each floor, signage is located that promotes people to take the stairs rather than the elevator. These design features meet the WELL v2 (IWBI, 2020) criteria for V03 circulation network – Parts 1-3.

The building is located in an urban part of Lisbon, within a 200 m walk distance of an existing cycling network, and an existing bus network that operates frequent trips on weekdays and weekends. All streets within 400 m of the building have continuous raised sidewalks and cycle lanes on both sides of the road, and a vehicular speed limit of 20km/h. Street segments intersect each other every 30m on average. Exterior building walls facing the pedestrian network incorporate windows on the first floor. A bike room is located on the ground floor of the building that can accommodate one bicycle from each flat. The bike room is equipped with a cupboard containing bike maintenance tools that are free for residents to use. Moreover, adjacent to the bike room there is a shower room and changing room with five lockers for use by residents. These design features meet the WELL v2 criteria for V04 Facilities for active occupants – Parts 1-2, and V05 Site planning and selection – Parts 1 and 2 (IWBI, 2020).

Although a children's playground is provided onsite, a dedicated fitness facility for residents is not provided by the design, and although residents have access to nearby gyms these are at a cost. Hence, the project does not meet criteria WELL v2 V08 Part 1 (but does meet V08 Part 2) and obtains a zero score for this criterion. The building also does not have a multi-purpose room available to residents, and hence does not meet the Fitwel (2020) criterion.

The score for B.4.4 is evaluated in Table 92 (corresponding to Excellent performance for this indicator). Having evaluated the scores for each indicator, B.4 is calculated in Table 93, corresponding to an excellent KPI performance class.

Table 92. Example of B.4.4 evaluation.

Metric	Score	Non-applicable[1]
Select single value below:		
The project does not comply with any of the following WELL v2 (IWBI, 2020) criteria (i.e. V02–V08).	x	
The project complies with the following WELL v2 criteria (i.e. V02–V08).	√ *Check next metrics.*	
WELL v2 criteria V02–V08 (multiple selections allowed):		
V02 Ergonomic workstation design – Parts 1-4	+15	☐
V03 circulation network[2]	+15	
V04 Facilities for active occupants	+15	
V05 Site planning and selection	+15	
V07 Active furnishings with Tier 1 **or** Tier 2 requirements	+20	☐
V08 Physical activity spaces and equipment (both Parts 1 and 2)	0	

The project also complies with the following criterion:		
Fitwel 8.7 Multi-purpose room (Fitwel 2020)	0	
Indicator score = Σ(metric scores)	**80**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score.
[2] Effort should be made to provide stairs as close as possible to the lifts, to reduce separation and provide a similar journey for people using the stairs and people using the lifts. Lifts should be easy to locate with appropriate wayfinding and signage. It should be ensured that any enhanced feature of the stair, such as music, artwork or game, does not create a safety hazard, disturbance or distraction to users who may be negatively impacted.

Source: JRC.

Table 93. Example of B.4 evaluation.

Indicator	**B.4.1**	**B.4.2**	**B.4.3**	**B.4.4**
Indicator score	95	77.5	100	80
Indicator performance class (indicative)	(Excellent)[1]	(Good)[1]	(Excellent)[1]	(Excellent)[1]
B.4 score	= 0.25 · 95 + 0.25 · 77.5 + 0.25 · 100 + 0.25 · 80 = 88.1			
B.4 performance class	Excellent			
B.4 performance class score ($PCS_{B.4}$)	100			

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

4.8 Improving accessibility of the built environment for everyone (B.5)

4.8.1 Description and assessment

The Physical Accessibility for Everyone KPI (B.5) evaluates the extent to which the project design provides ease of physical access in terms of three indicators:

- *Ease of circulation (B.5.1)*: extent to which movement of different users through, around and between spaces and environments is enabled without barriers and without compromise to their safety and experience.
- *Safe wayfinding (B.5.2)*: extent to which the design conveys spatial information to users to help them identify and comprehend the various elements within the environment around them.
- *Usability and operation (B.5.3)*: extent to which the design is usable and operable by all users, regardless of their abilities or background.

B.5 score is evaluated according to Equation (160).

$$B.5 = \sum_{j=1}^{3}\left(w_{B.5.j} \cdot B.5.j\right) \Big/ \sum_{j=1}^{3}\left(w_{B.5.j}\right) = 0.33 \cdot (B.5.1 + B.5.2) + 0.34 \cdot B.5.3 \leq 100 \qquad (160)$$

Each indicator is evaluated with a score between 0-100 and a corresponding indicative performance class (indicator class is provided just to guide users but not used further in the evaluation of KPIs and dimensions), according to adherence with best-practice design guidance, and beyond best-practice standards and guidance that are typically voluntary. The performance class of the B.5 KPI is assessed according to the thresholds in Figure 69.

Figure 69. B.5 performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
B.5 thresholds ($t_{B.5}$):	$0 \leq$	$t_{B.5,\ Acceptable} \geq 40$	$t_{B.5,\ Good} \geq 60$	$t_{B.5,\ Excellent} \geq 85$	≤ 100

Source: JRC.

The KPI and its indicators are designed to be implemented at all project scales, types and main uses (Table 48). The assessment of B.5.1, B.5.2 and B.5.3 is affected by the project scale and type.

When a project, classified into the neighbourhood or urban scale, involves several buildings with distinct design characteristics, thus likely leading to different indicator scores for each of them, the evaluation of the indicators shall be carried out by identifying representative samples of buildings with similar design features. For each of these representative building designs, a separate assessment should be performed. The overall score per indicator is then estimated as a weighted average of the separate assessment scores, with the weights obtained from the relative occurrence of each building design.

For renovation projects, the assessment focuses on the specific aspects of the building and spaces that are affected by the proposed renovation works. However, when indicators and/or metrics address an aspect that has not been altered by the renovation, their evaluation should consider the as-built state (i.e. condition before the intervention is set), as this contributes to the accessibility of the built environment.

The evaluation of the indicators within B.5 is conducted by the design team, comprising architects and service engineers, potentially seeking the advice of product manufacturers, and main and specialist contractors. The assessment requires the following information to be identified and collected:

- Standards, guidelines and certification scheme documents, as well as any national standards relevant to universal design and design for disabilities.
- Information of the project location and relation to roads, pedestrian areas, cycle lanes and public transportation.
- Project design plans, architectural and structural design drawings, service plans.
- Plans for the use of different areas of the project, with identification of regularly occupied individual and multi-occupant spaces.
- Information on the type of users and their needs.
- Characteristics of internal finishes (ceiling, walls, flooring), and manufacturer information regarding the light reflectance value (LRV) of surfaces and finishes.
- Specifications of doors, handles, handrails, toilets, sinks, seating, furniture and other fixings.
- Details on design, specifications and placement of controls and switches.
- Plans and information on the location of signage and its visual and tactile characteristics.
- Information on means of delivery and content of acoustic messaging and cues in the design.

4.8.2 Ease of circulation (B.5.1)

The Ease of circulation indicator (B.5.1) evaluates the extent to which the project design enables the movement of different users through, around and between spaces and environments without barriers and without compromise to their safety and experience. It focuses on evaluation of the adequacy of entrances, horizontal circulation (e.g. across a building floor) and vertical circulation (i.e. access to other floors). As the provision of adequate circulation comprises numerous design elements, the indicator evaluation is based on compliance with best practice standards and beyond best-practice guidance that specifically addresses users with diverse abilities.

The evaluation of the indicator score is summarised in Table 94. The indicator score cannot exceed 100. On some occasions, next to the metrics of the indicator, a “non-applicable” option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects.

Figure 70 shows indicator thresholds adopted to associate the indicator score to an indicator performance class. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

EN 17210 (CEN, 2021b) sets out performance objectives for safe physical accessibility for different users in several sections of the standard, covering indoor circulation and access to the project from the exterior. Particular care is given to consider the needs of users with mobility impairments, including those using wheelchairs or walking aids. EN 17210 also promotes consultation with users to identify their needs for physical accessibility.

This standard is considered current best-practice. Hence, non-compliance with this performance standard results in an indicator score of zero. An indicative Acceptable performance class for the indicator is based (at a minimum) on compliance with EN 17210 (CEN, 2021b) using national guidelines. A higher indicator score can be achieved by demonstrating compliance with the EN 17210 performance criteria using the specifications included in TR 17621 (CEN, 2021c) (or alternative national guidance that provides equal or more stringent criteria than TR 17621). Higher indicator scores can also be achieved by implementing enhanced design criteria that have been derived from BS 8300-2 (BSI, 2018), Irish Technical Guidance Document M (DHLGH, 2022), DIN 18040-1 (DIN, 2010) and PAS 6463 (BSI, 2022). The enhanced criteria are grouped into categories according to the area or asset that they relate to in the project design. Each category of enhanced criteria is assigned a maximum score to ensure that an Excellent indicative performance class for B.5.1 cannot be achieved without enhanced design features across the entire project. Accordingly, if either all relevant criteria within a category are satisfied, or all criteria within a category are non-applicable, the maximum score of the category is achieved.

Table 94. B.5.1 score.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project does not comply with the EN 17210 (CEN, 2021b) sections listed below.	B.5.1 = 0. No further points to be added.	
The project complies with the following EN 17210 sections:[2]	*Check next metrics.*	
9.1.1–2, 9.1.4–6, 9.1.10–11, 9.1.13–14 Entrances		
9.2.1–2, 9.2.4–7 Corridors and passageways		☐
9.3.1–5 Doors		
9.5.1–3 Patios, balconies and terraces		☐
10.1.1–7,10.1.10, 10.1.12-13 Ramps		☐
10.2.1–5, 10.2.10-12 Steps and stairs		
10.3.1–3 Handrails		
10.4.1–4 Lifts		☐
10.5 Vertical and inclined lifting platforms		☐
10.6 Escalators and moving walks		☐
11.1.1–6 Service counters for information, ticketing and reception		☐
11.2.1–3 Waiting and queuing areas		☐
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with accessible design criteria that are less stringent than TR 17621 (CEN, 2021c).	+20	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent accessible design criteria.	+40	
The project also complies with the following enhanced design features (multiple selections allowed but a maximum score applies to each category):		
Category: Entrances and doors	(≤15)	
Entrance doors and internal lobby doors have a min clear width of 1.00 m.	+5	
Minimum clear width of internal doors is 0.85 m (including accessible toilets).	+5	
Minimum 0.70 m of clear space is provided at the latch side of the door.	+2.5	
Side-hung gates are self-closing.	+2.5	☐
Where there is risk of crowding, alternative entrances and exits are provided with clear signage, or appropriate management procedures.	+5	☐
Entrance canopy (if provided) extends beyond the door width for at least 1.25 m to accommodate a wheelchair and provide sufficient space to avoid the direct flow of people using the entrance doors.	+2.5	☐
If a large entrance canopy is provided, seating allows a person or people to pause and reset before entering or leaving. Materials used at entrance canopy do not accentuate the sound of rain or similar.	+2.5	☐
Category: Corridors, passageways and other spaces	(≤15)	
Corridors have a minimum unobstructed width of 1.80 m between handrails or other projections.	+5	☐
Minimum turning space of 1.50m · 1.50m is achieved for wheelchair users for a turn of 90 degrees.	+5	☐

Long narrow corridors are avoided, or are broken up using windows on side walls, intersections, and recesses, and if dead-end corridors are provided, they incorporate a seating area.	+5	☐
Places to pause or break a journey are provided, for example with seating, allowing people to reset and recharge before continuing.	+5	☐
Category: Steps and stairs	(≤10)	
There are no spiral, helical or curved stairs.	+5	☐
There are no skewed stairs or stair winders.	+5	☐
Minimum distance of 3.00 m is provided between descending stairs located opposite lift doors and the lift doors.	+5	☐
Category: Lifts, vertical and inclined lifting platforms, escalators and moving walks	(≤15)	
An alternative to escalators and moving walks is provided.	+5	☐
Clear manoeuvring space in front of lift car entrance and inclined lifting platforms is minimum 1.80 m in diameter.	+5	☐
Clear width of vertical lifting platform doors at landing is a minimum of 0.90 m.	+5	☐
Lift cars do not have black or dark floor finishes.	+2.5	☐
A small mirror in a lift is provided to facilitate safe reversing for wheelchair users. A large mirror is avoided as it can be frightening for people with dementia.	+2.5	☐
Category: Service counters for information, ticketing and reception	(≤5)	
Manoeuvring space in front of service counters is minimum 1.80 m in diameter.	+5	☐
Reception/information counters are identifiable from the main point of entry.	+5	☐
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score. If satisfied and non-applicable metrics result in a score higher than the maximum within a category, then the maximum score of the category is applied.

[2] If the section of EN 17210 does not apply to the project (i.e. non-applicable is selected), then as long as all other stated sections are complied with, then the project is deemed to be in compliance with EN 17210.

Source: JRC.

Figure 70. B.5.1 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.5.1 thresholds ($t_{B.5.1}$):	0 ≤		$t_{B.5.1, Acceptable}$ ≥ 20		$t_{B.5.1, Good}$ ≥ 50		$t_{B.5.1, Excellent}$ ≥ 80		≤ 100

Source: JRC.

4.8.3 Safe wayfinding (B.5.2)

The Safe wayfinding indicator (B.5.2) evaluates the extent to which the design conveys spatial information to users to help them identify and comprehend the various elements within the environment around them. This includes spatial information to aid orientation and navigation and use of the space without harm or compromise. In particular it looks at whether: (*i*) sufficient visual contrast is provided to ensure users can easily identify and comprehend the various elements within the environment, (*ii*) finishes are safe, clear and void of elements or patterns which may create confusion to users, (*iii*) signage, information and communication systems provide the necessary information for users to navigate and use the space independently and with confidence, including alternative formats for people with specific needs. As numerous design elements need to be considered, evaluation of this indicator is based on the level of design adherence to best practice and beyond best-practice design guidance that specifically addresses users with diverse abilities.

The evaluation of the indicator score is summarised in Table 95. The indicator score cannot exceed 100. On some occasions, next to the metrics of the indicator, a "non-applicable" option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects. Figure 71 shows indicator thresholds adopted to associate the indicator score to an indicator performance class. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

EN 17210 (CEN, 2021b) sets out performance objectives for safe wayfinding and orientation for different users in several sections. These mainly cover indoor wayfinding and access to the project from the exterior, as well as clarity of signage and messaging. The EN 17210 standard provides design guidance for users of different ages and with physical impairments (e.g. mobility, auditory and visual impairments), and is considered current best-practice. Hence, non-compliance with this performance standard, results in an indicator score of 0. An Acceptable indicative performance class is based (at a minimum), on compliance with EN 17210 using national guidelines. A higher indicator score can be achieved by demonstrating compliance with the EN 17210 performance criteria using the specifications provided in TR 17621 (CEN, 2021c) (or alternative national guidance that provides equal or more stringent criteria than TR 17621). Higher indicator scores can also be achieved by implementing enhanced design criteria that also account for users with neurodiversity, and which derive from BS 8300-2 (BSI, 2018), ISO 19028 (ISO, 2016), NS 11001-1 (NS, 2018) and PAS 6463 (BSI, 2022). The enhanced criteria are grouped into categories according to the area, asset or design feature that they relate to in the project design. Each category of enhanced criteria is assigned a maximum score to ensure that an Excellent indicative performance for B.5.2 cannot be achieved without enhanced design features across the entire project. Accordingly, if either all relevant criteria within a category are satisfied, or all criteria within a category are not applicable, the maximum score of the category is achieved.

Visual contrast is adopted as one of the wayfinding cues in built environment projects. It is defined as the visual perception between elements of a building (TR 17621). Visual contrast may be obtained by a combination of luminance contrast and colour contrast. Since people with impaired vision can rely only on luminance contrast, this is used in TR 17621 for visual contrast determination. As stated in Annex A of TR 17621, three main methods can be adopted for the estimation of luminance contrast, i.e. the Michelson contrast formula, the Weber contrast formula, and the light reflectance value (LRV) difference. The three methods are not comparable, and the selected method should be used consistently when adhering to the specifications provided in TR 17621. In the B.5.2 enhanced criteria, the LRV difference is used. LRV is defined as the proportion of visible light reflected by a surface at all wavelengths and directions, when illuminated by a light source. The LRV scale ranges from 0, which is a perfectly absorbing surface that could be assumed to be totally black, up to 100, which is a perfectly reflective surface that may be considered as the perfect white (BSI, 2018). For the selection of colours and materials during a planning procedure, the use of LRV is regarded to be appropriate as LRV values may be provided by the supplier of the colour system or can be measured with samples in a laboratory (see BS 8300-2, BSI, 2018 Annex B). The LRV difference is the point difference between the LRV values of two surfaces. Differences less than 20 points may not give adequate visual contrast, even with an illuminance of 200 lx on the surfaces (BSI, 2018).

Table 95. B.5.2 score.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project does not comply with the EN 17210 (CEN, 2021b) sections listed below.	B.5.2 = 0. No further points to be added.	
The project complies with the following EN 17210 sections:[2]	*Check next metrics.*	
6.1 Wayfinding, orientation and navigation		
6.2 Wayfinding information		
6.3.1-3 Wayfinding - visual contrast		
6.4 Tactile information		
6.5 Audible information and hearing enhancement		
6.6 Signage		
6.7 Graphical symbols		
9.1.3, 9.1.7, 9.1.9 Entrances		
9.2.3, 9.2.12–14 Corridors and passageways		☐
9.3.10 Doors		
9.6 Surface finishes and materials		
10.3.6–7 Handrails		
10.4.8 Lifts		☐
11.1.7–8 Service counters for information, ticketing and reception		☐
11.2.4–5 Waiting and queuing areas		☐
11.3.11 Seating and resting areas		☐
13.1 User interface, controls and switches – rationale		
13.2 Public ICT information screens		☐

13.3 ICT user interfaces		
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with wayfinding design criteria that are less stringent than TR 17621 (CEN, 2021c).	+20	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent wayfinding design criteria.	+40	
The project also complies with the following enhanced design features (multiple selections allowed but a maximum score applies to each category):		
Category: Tactile information	(≤5)	
The maximum size of a tactile map is 0.60 m high · 1.00 m wide.	+5	
The height of the relief of raised tactile letters, figures and graphical symbols is 1.00–1.50 mm.	+5	
Category: Signage and public ICT information screens	(≤15)	
Signs are separated from other notices and pictures to avoid a cluster of competing information.	+2.5	☐
Signage has both symbols and words (except for universally accepted or mandatory safety symbols or pictures), is concise and easy to interpret, and contrasts from the surface it is mounted on (light reflectance value (LRV) difference ≥ 70).	+5	☐
Signage uses consistent terminology in the built environment, digitally, and in any other medium.	+5	☐
Directional signage is visible from all directions of approach, where practicable, and repeated at each decision and reassurance point.	+5	☐
Location signs confirm arrival at destinations.	+5	☐
The position of ICT screens above head height are at a minimum height of 2.30 m.	+5	☐
Category: Steps, stairs, lifts, vertical and inclined lifting platforms, escalators and moving walks	(≤10)	
Steps and escalators have a strong visual contrast (LRV difference ≥ 70 points) to the edge of the tread and riser.	+5	☐
Bold or intense patterns are avoided on walkways or stairs.	+5	☐
Category: Wayfinding	(≤15)	
Information and wayfinding are provided in at least two sensory formats, including visual, audible, and tactile.	+5	
Opportunities to preview spaces such as through glazing, from outside or within the building, are provided where appropriate.	+5	
Unique and highly visible features are positioned in strategic locations to assist in wayfinding.	+2.5	
In complex visitor destinations, help points are provided at key intervals.	+2.5	☐
Key amenities (e.g. WCs, baby change, tea points, first-aid, restorative rooms) are located consistently throughout the building so they are found in a similar position on all floors.	+5	
Category: Colours and patterns	(≤10)	
Vivid colours are kept to a minimum (to avoid overwhelm), and if red is used, especially on a white background, it is used sparingly (red causes difficulties for some people).	+5	
Large areas (including floors) of highly contrasting geometric or repetitive patterns (LRV difference ≥ 30 points) and patterns in three dimensional forms (including shadow patterns) are avoided.	+5	
Visual contrast (LRV difference ≥ 15 points) between adjacent floor finishes is avoided, or one or more incremental bands that are ≥ 50mm deep are provided to create a graduated change between the two primary surfaces.	+5	
Category: Information	(≤5)	
Pre-visit preview information provides information about the environment, what to expect during a visit, and journey information. Preview information is available before the visit (e.g. virtual flythrough videos, audio description, building plans) as well as upon arrival.	+5	☐
If crowds are inevitable at predictable times, these timings are publicised so that people can avoid them, alongside provision of well signposted restorative spaces.	+5	☐
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score. If satisfied and non-applicable metrics result in a score higher than the maximum within a category, then the maximum score of the category is applied.

[2] If the section of EN 17210 does not apply to the project (i.e. non-applicable is selected), then as long as all other stated sections are complied with, then the project is deemed to be in compliance with EN 17210.

Source: JRC.

Figure 71. B.5.2 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent
B.5.2 thresholds ($t_{B.5.2}$):	0 ≤	$t_{B.5.2, Acceptable}$ ≥ 20	$t_{B.5.2, Good}$ ≥ 50	$t_{B.5.2, Excellent}$ ≥ 80	≤ 100

Source: JRC.

4.8.4 Usability and operation (B.5.3)

The Usability and operation indicator (B.5.3) evaluates the extent to which the project is usable and operable by all users, regardless of their abilities or background. This indicator focuses on whether the necessary and desired facilities for people with diverse needs are available, and whether usable and operable elements within the space, such as furnishings, fixtures and fittings, are easy to use and operate by all users.

The evaluation of the indicator score is summarised in Table 96. The indicator score cannot exceed 100. On some occasions, next to the metrics of the indicator, a "non-applicable" option exists, so that users can indicate that the specific metric is not relevant to the project attributes. If the non-applicable option is selected (when available), the full metric score should be considered in the evaluation of the indicator score, to avoid penalising a project due to non-relevant aspects. Figure 72 shows indicator thresholds adopted to associate the indicator score to an indicator performance class. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

EN 17210 (CEN, 2021b) sets out performance objectives for usability and operation for different users in several sections, and mainly considers the needs of users of different ages and with physical impairments (e.g. mobility, auditory and visual impairments). The EN 17210 standard is considered current best-practice, and similarly to B.5.1 and B.5.2, non-compliance with it, results in an indicator score of 0. An Acceptable indicative performance class is based (at a minimum) on, compliance with EN 17210 using national guidelines. A higher indicator score can be achieved by demonstrating compliance with the EN 17210 performance criteria using the specifications provided in TR 17621 (CEN, 2021c) (or alternative national guidance that provides equal or more stringent criteria than TR 17621). Higher indicator scores can also be achieved by implementing enhanced design criteria that provide enhanced specifications and address users with neurodiversity. These derive from BS 8300-2 (BSI, 2018), ISO 21542 (ISO, 2021), ONORM B 1600 (ASI, 2017), PAS 6463 (BSI, 2022) and WELL v2 (IWBI, 2020). The enhanced criteria are grouped into categories according to the area, asset or design feature that they relate to in the project design. Each category of enhanced criteria is assigned a maximum score. This is done to ensure that an Excellent performance for B.5.3 cannot be achieved without enhanced design features across the entire project. Accordingly, if either all relevant criteria within a category are satisfied, or all criteria within a category are not applicable, the maximum score of the category is achieved.

Table 96. B.5.3 score.

Metric	Score	Non-applicable[1]
Select single value below:		
The project does not comply with the EN 17210 (CEN, 2021b) sections listed below.	B.5.3 = 0. No further points to be added.	
The project complies with the following EN 17210 sections:[2]	*Check next metrics.*	
9.3.7–8, 9.3.12–14 Doors		
9.4.1–5 Windows		
10.3.5 Handrails		
10.4.5–6, 10.4.12 Lifts		☐
11.2.6 Waiting and queuing areas		☐
11.3.1–10, 11.3.12 Seating and resting areas		☐
11.4 Storage areas, lockers and baggage storage		☐
11.5 Kitchen areas and kitchenettes		☐
11.6 Facilities for assistance dogs		
12.1.1–7 Accessible toilets		
12.2 Toilets for general use		
12.3 Sanitary facilities for other users		

12.4 Showers and bathrooms 13.4 User interface, controls and switches – controls and switches 13.5 User interface, controls and switches – examples of general use elements		
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with usability and operation design criteria that are less stringent than TR 17621 (CEN, 2021c).	+20	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent usability and operation design criteria	+40	
The project also complies with the following enhanced design features (multiple selections allowed but a maximum score applies to each category):		
Category: Doors	(≤10)	
Operating force of maximum 15 N for manually operated doors without door closers.	+5	
A horizontal supportive grab bar is provided for doors wider than 0.85 m and for the inside face of accessible toilet doors.	+5	
All manually operated door opening hardware is lever action.	+2.5	☐
Category: Lifts	(≤5)	
Lift cars have a min of one handrail on each car wall, only interrupted by the operating panel, with the free space between the wall and the gripping part at least 50 mm.	+5	☐
Category: Kitchen areas and kitchenettes	(≤5)	
Cupboard doors have a 180-degree opening.	+2.5	☐
Pull-out shelves in kitchen areas and kitchenettes are fitted immediately below the work surface.	+2.5	☐
Refrigerators and freezers are fitted as separate units on a plinth with a min. height of 0.20 m.	+2.5	☐
Category: User interface, controls and switches	(≤15)	
Where card slots are provided, they are between 0.80-0.90 m above floor.	+2.5	☐
Minimum distance from control to internal corners is 0.70 m.	+5	
Height of controls above floor surface is between 0.80 m and 1.10 m.	+5	
Fixtures and controls are low noise where practicable (e.g. soft close cupboards and toilet lids, quiet flush WC systems). Where provided, quiet hand dryers (maximum 70 dB) are selected.	+5	
Fittings, switches, controls and technology are intuitive and simple to use. Additional simple directions for use are provided.	+5	
Category: Facilities	(≤20)	
WELL v2 (IWBI, 2020) V04 Facilities for Active occupants – Part 2 criteria are met.	+5	☐
WELL v2 (IWBI, 2020) C09 New mother support – Part 2 criteria are met.	+5	
Sanitary facilities (including WCs, changing rooms and showers where provided) are ambulant-accessible, wheelchair-accessible (including wheelchair-accessible for children), and appropriate for use by obese and bariatric users.	+5	
There is provision for self-contained WCs (with sink inside and within reach from the toilet bowl), baby changing facilities (for all genders), and stoma management within WCs.	+5	
First aid/medical facilities and equipment are provided in sufficient quantities for the number of users.	+5	
Category: Restorative spaces	(≤10)	
WELL v2 (IWBI, 2020) M07 Restorative spaces criteria are met.	+5	
Space(s) for practice of faith and/or contemplation are provided.	+5	☐
Where a large space is provided, smaller areas within the space allow retreat, or variation in ceiling heights is provided, with lower ceiling creating a more intimate quiet space.	+5	☐
Category: Furnishings	(≤5)	
A mix of furniture styles is used to meet a variety of user needs and settings. This includes ergonomic considerations, including sit-stand desks, and different seat heights and support features, giving people options and choices to find the most suitable solution for their requirements.	+5	
Indicator score = Σ(metric scores)	**≤ 100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score. If satisfied and non-applicable metrics result in a score higher than the maximum within a category, then the maximum score of the category is applied.

[2] If the section of EN 17210 does not apply to the project (i.e. non-applicable is selected), then as long as all other stated sections are complied with, then the project is deemed to be in compliance with EN 17210.

Source: JRC.

Figure 72. B.5.3 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent
B.5.3 thresholds ($t_{B.5.3}$):	0 ≤	$t_{B.5.3, Acceptable}$ ≥ 20	$t_{B.5.3, Good}$ ≥ 50	$t_{B.5.3, Excellent}$ ≥ 80	≤ 100

Source: JRC.

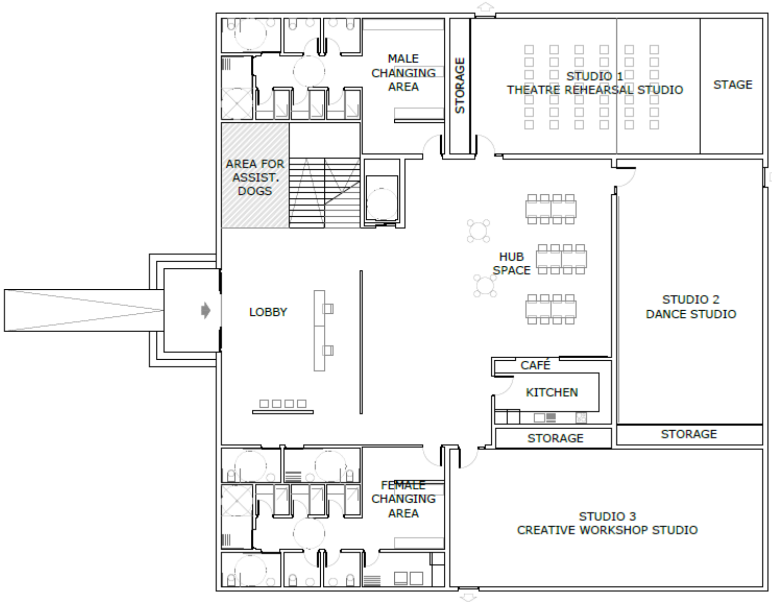
4.8.5 Example (B.5)

In this example a renovation project type for non-residential main use is considered. The assessment is carried out at the building scale. A textile factory, built in the 1800s, is sited in Lyon, France. Once at the outskirts of the city, with increasing urban development, it is now sited in a mixed-use area that combines residential and light commercial properties. A two-storey building, part of the textile factory complex, is renovated and transformed into a community facility for performing arts. The building provides the case study for the B.5 evaluation example (Figure 73). The community facility will be used by schools, community groups and charities. The latter includes a charity that promotes performing arts in adults with intellectual limitations or learning disabilities, many with co-occurring physical, visual and hearing impairments.

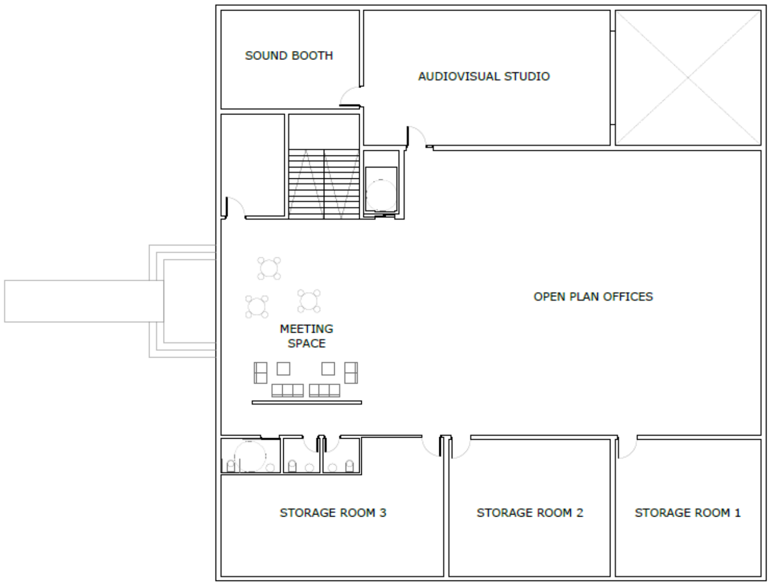
On the ground floor, the renovation includes three new studio spaces, each with a specific use: creative workshop studio, dance studio and full theatre rehearsal studio. These branch out from a central community meeting space and a café. The studios form three sides of the central space. The fourth side includes at its centre the main entrance and lobby with a reception desk, two accessible toilets and a stair and lift for accessing the second floor. Female and male changing rooms (containing showers and further toilets) are on both sides of the lobby. The second floor of the building includes two storage rooms, office space with two accessible toilets and a technical studio and sound booth that serves the theatre rehearsal studio. To enhance ease of use, corridors are avoided throughout the renovated building.

Figure 73. Fictitious community centre plans.

Ground floor:



First floor:



Source: JRC.

Ease of circulation (B.5.1) is evaluated according to the metrics of Table 94.

Access, entrances and doors: Most users access the studios by public transportation. Others use door-to-door paratransit service and arrive at a drop-off zone, just beyond the building entrance. A public road runs in parallel to the façade, and is one of the few that intersects the complex of green space and multi-block textile factory buildings. Access from street level to the main entrance is provided via three steps, as well as by a ramp, which leads onto a landing. The landing is 2.50 m wide and 4.00 m in length, exceeding the minimum dimensions needed for wheelchair manoeuvring (CEN, 2021c, section 9.15(b)). The landing is fully covered by a canopy that cantilevers out from the building, providing headroom of 2.20 m. The landing is at the same level with the entrance and main lobby, whereas gratings are provided on the landing in front of the main entrance doors to prevent dirt being brought in. The main entrance comprises automatic sliding doors with a stop mechanism, opearated via a movement sensor or manually by pressing a clearly visible button that is mounted on a post.

The sliding doors provide a clear width of 1.50 m and clear height of 2.00 m. A silver-coloured intercom system is provided on the wall at the side of the door at a height of 0.90 m above floor level. An emergency exit is provided in each of the three studios, and each exit provide direct step-free access to the streets, surrounding the building. Emergency exit devices are operated by a horizontal bar. All internal doors (e.g. to the changing rooms, offices, accessible toilets) are 1.00 m wide, except for the internal doors to the studio, which are 1.80 m wide double doors. No risk of crowding is identified. The entrance and door features meet the requirements of EN 17210 (CEN, 2021b) with the specifications of TR 17621 (CEN, 2021c). Enhanced criteria for the entrance doors, internal doors and canopy size are met, but not for the canopy seating area. The enhanced criterion for an automated door is met. As there are no side-hung gates, the related enhanced criterion does not apply.

Corridors, passageways and other spaces: To enhance ease of use, corridors are avoided in the renovation design. An open space of 2.00 m · 2.00 m is provided in front of the lift for wheelchair manoeuvring. The building is composed of large open spaces in general (i.e. studios and central community meeting area), with most furniture either being on castors (with brakes) or light enough to be re-arranged freely. The central community meeting area and café provide a place of rest in transition between the lobby and studios. The corridors, passageways and other spaces meet the requirements of EN 17210 with the specifications of TR 17621. Enhanced criteria for the minimum turning spaces, avoidance of corridors and spaces of rest are met. The enhanced criterion of minimum unobstructed width of corridor does not apply.

Patios, balconies and terraces: There are none in the case study.

Ramps, steps and stairs: The only ramp in the project is a straight ramp that provides access from street level to the landing in front of the main entrance. The ramp rise is 0.45 m with a gradient of 1:17 (5.9%) and length of 7.66 m. The ramp clear width is 1.5 m, allows frequent two-way traffic (permitting a walking person and a wheelchair user to pass each other). Two handrails are provided, which extend 0.30 m beyond the end of the ramp at both ends. The ramp is equipped with an upstand at each side of height 0.15 m. A flight of steps (3 steps) is provided in addition to the ramp. These steps have a rise of 0.15 m and a going of 0.30m. An internal staircase exists between the ground and first floor of the building. This is sited adjacent to the lift and has a half turn intermediate landing of 1.70 m depth, located 10 steps up from the ground floor. The internal staircase has an unobstructed width of 1.50 m and surface width of 1.70 m (allowing for handrails), which is adequate for evacuation use. Handrails are provided that are continuous across the stairs and landing, and extend 0.30m horizontally beyond the first and last step of each flight of stairs. The ramps, steps and stairs meet the requirements of EN 17210 considering the specifications of TR 17621. Enhanced criteria for avoiding curved and skewed stairs are met. The enhanced criterion regarding siting of stairs opposite to lifts does not apply, as the stairs are located adjacent to the lift.

Lifts, vertical and inclined lifting platforms, escalators and moving walks: There are no vertical or inclined lifting platforms, escalators or moving walks in the project. A lift is provided to facilitate access between the ground and first storey of the building. The lift has a size of 1.50 m · 2.10 m, which can accommodate one wheelchair and one additional passenger, allowing wheelchair rotation within the car. The lift is large enough to allow use with a stretcher in case of emergency. The lift is not equipped with a small mirror. As previously stated, an open space of 2.00 m · 2.00 m is provided in front of the lift for wheelchair manoeuvring. The lift meets the requirements of EN 17210 considering the specifications of TR 17621. The lift does not meet the enhanced criterion of provision of small mirror in the lift for wheelchair manoeuvring, but it does meet the enhanced criterion for space in front of the lift. The lift meets the enhanced criteria for colour.

Service counters for information, ticketing and reception, waiting and queuing areas: The reception desk, which is 0.80 m high, is directly in front of the main entrance. An open space of 2.50 m · 4.00 m (depth by width) is provided in front of the reception desk and a seating for 4 people is provided adjacent to the entrance. A 0.70 m clear height and 0.30 m recess is provided under the reception desk, at the front, to allow approach from people in wheelchairs. The reception and waiting areas meet the requirements of EN 17210 considering the specifications of TR 17621, and meet both the relevant enhance criteria.

B.5.1 score is in Table 97 (corresponding to Excellent performance for this indicator).

Table 97. Example of B.5.1 evaluation.

Metric	Score	Non-applicable[1]
Select single value below:		
The project does not comply with the EN 17210 (CEN, 2021b) sections listed below.	x	
The project complies with the following EN 17210 sections:[2]	√ *Check next metrics.*	
9.1.1–2, 9.1.4–6, 9.1.10–11, 9.1.13–14 Entrances		
9.2.1–2, 9.2.4–7 Corridors and passageways		☒
9.3.1–5 Doors		
9.5.1–3 Patios, balconies and terraces		☒
10.1.1–7,10.1.10, 10.1.12-13 Ramps		☐
10.2.1–5, 10.2.10-12 Steps and stairs		
10.3.1–3 Handrails		
10.4.1–4 Lifts		☐
10.5 Vertical and inclined lifting platforms		☒
10.6 Escalators and moving walks		☒
11.1.1–6 Service counters for information, ticketing and reception		☐
11.2.1–3 Waiting and queuing areas		☐
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with accessible design criteria that are less stringent than TR 17621 (CEN, 2021c).	0	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent accessible design criteria.	+40	
The project also complies with the following enhanced design features (multiple selections allowed but a maximum score applies to each category):		
Category: Entrances and doors	(≤15) *category max score applies*	
Entrance doors and internal lobby doors have a min clear width of 1.00 m.	+5	
Minimum clear width of internal doors is 0.85 m (including accessible toilets).	+5	
Minimum 0.70 m of clear space is provided at the latch side of the door.	+2.5	
Side-hung gates are self-closing.	+2.5	☒
Where there is risk of crowding, alternative entrances and exits are provided with clear signage, or appropriate management procedures.	+5	☒
Entrance canopy (if provided) extends beyond the door width for at least 1.25 m to accommodate a wheelchair and provide sufficient space to avoid the direct flow of people using the entrance doors.	+2.5	☐
If a large entrance canopy is provided, seating allows a person or people to pause and reset before entering or leaving. Materials used at entrance canopy do not accentuate the sound of rain or similar.	+2.5	☐
Category: Corridors, passageways and other spaces	(≤15) *category max score applies*	
Corridors have a minimum unobstructed width of 1.80 m between handrails or other projections.	+5	☒
Minimum turning space of 1.50m · 1.50m is achieved for wheelchair users for a turn of 90 degrees.	+5	☐
Long narrow corridors are avoided, or are broken up using windows on side walls, intersections, and recesses, and if dead-end corridors are provided, they incorporate a seating area.	+5	☒
Places to pause or break a journey are provided, for example with seating, allowing people to reset and recharge before continuing.	+5	☐
Category: Steps and stairs	(≤10) *category max score applies*	
There are no spiral, helical or curved stairs.	+5	☐
There are no skewed stairs or stair winders.	+5	☐
Minimum distance of 3.00 m is provided between descending stairs located opposite lift doors and the lift doors.	+5	☒
Category: Lifts, vertical and inclined lifting platforms, escalators and moving walks	(≤15) *category max score applies*	

An alternative to escalators and moving walks is provided.	+5	☒
Clear manoeuvring space in front of lift car entrance and inclined lifting platforms is minimum 1.80 m in diameter.	+5	☐
Clear width of vertical lifting platform doors at landing is a minimum of 0.90 m.	+5	☒
Lift cars do not have black or dark floor finishes.	+2.5	☐
A small mirror in a lift is provided to facilitate safe reversing for wheelchair users. A large mirror is avoided as it can be frightening for people with dementia.	0	☐
Category: Service counters for information, ticketing and reception	(≤5) *category max score applies*	
Manoeuvring space in front of service counters is minimum 1.80 m in diameter.	+5	☐
Reception/information counters are identifiable from the main point of entry.	+5	☐
Indicator score = Σ(metric scores)	**100**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score. If satisfied and non-applicable metrics result in a score higher than the maximum within a category, then the maximum score of the category is applied.

[2] If the section of EN 17210 does not apply to the project (i.e. non-applicable is selected), then as long as all other stated sections are complied with, then the project is deemed to be in compliance with EN 17210.

Source: JRC.

Safe wayfinding (B.5.2) is evaluated according to the metrics of Table 95.

In the community centre for performing arts, safety information includes signage for hazardous areas (including stairs), accessible evacuation routes and fire extinguishers. These are placed at 1.50 m and 2.20 m heights to allow them to be read and seen at a distance, respectively. They are located away from other signage to avoid confusion and have an LRV difference of 60 with respect to surrounding background. Information concerning fire safety and evacuation procedures is provided at all entrances and final emergency exits. Approaches to the entrance ramp and steps from above and below are highlighted with a coloured strip of width equal to 0.10 m that provides a visual contrast with the landing and ramp surfaces (LRV difference of 60 points). At the internal staircase, a visually contrasting line with a width of 0.04 m is provided on the front edge of the going in each step with LRV 80 points, which extends across the width of the step. The LRV value for the step surface is 20 points, thus the LRV difference is 60 points and lies within the accepted range for hazard zones in figure A.3 in TR 17621. All handrails are coloured to have an LRV difference of 30 with respect to the adjacent wall. The handrails are provided with raised Braille script at locations along their length that indicates the direction of fire evacuation. Tactile walking surface indicators (TWSI) with attention patterns (based on ISO 23599, ISO, 2019), and with profile heights of 4mm, rounded edges and LRV differences of 50 points with respect to surrounding surfaces, are used on the landings at the top and bottom of the outdoor steps and ramp. TWSI with similar specifications are also used at the top bottom of each flight of stairs indoors. These TWSI extend the full width of the stairs (and ramp), are set back 0.30 m from the hazard and extend 0.60 m in the perpendicular direction. The café kitchen, a potentially hazardous area, is set behind a door and accessible by a programmed lock system.

Information for wayfinding includes signage in the reception area that indicates the location of the stairs and lift, changing rooms, toilets, and throughway to the community meeting area and studios, as well as directional signage from the central community meeting area to the studios. Signs are designed for maximum readability; therefore, font, text size, spacing, and alignment are chosen based on their ability to communicate messages clearly and directly. Standard and recognisable symbols, icons and pictograms are used along with text and braille. A consistent terminology is used in all signage, and other visual, acoustic and tactile messaging. The height of the relief of raised tactile letters, figures and graphical symbols is 1 mm. Appropriate lighting is provided for readability of signs. The specifications of TR 17621 sections 6.6 and 6.7 are met. Signs stating arrival at a point of interest are provided. A tactile map 0.5 m high by 0.5 m wide is provided at the reception area on a stand which angles the map at 20 degrees to the horizontal. Audible and visual information is provided through accessible public ICT screens in the reception area and central community meeting space, placed at 1.60 m height. No public ICT screens are placed at higher height. A hearing enhancement system is installed in each of the performance studios.

Important wayfinding features in the project are highlighted through visual contrast complemented by acoustic or tactile cues. Moderate visual contrast is provided between large surface areas (floor, walls and ceilings), with LRV difference between adjoining large surfaces being in the range of 30 to 40 points throughout the building, which meets the TR 17621 requirement of LRV difference equal to or higher than 30 points for large surfaces. The entrance to the building is easily identifiable due to the large canopy. Moreover, the sliding doors of the entrance are transparent and have a white frame (LRV = 83 points) that visually contrasts against the exterior brick (LRV = 30 points) façade of the building (LRV difference = 53 points). The doors have horizontal contrasting markings on the glazing that highlight its presence and indicate where the door opens. Smaller items that enable the use of building elements, such as the intercom at the front entrance and door handles, have an LRV difference equal to or higher than 70 points with respect to adjoining surfaces. A grating is located on the landing in front of main entrance doors. The grating has a length of 2.00 m and slots with mesh width 0.01 m and mesh length 0.02 m. The grating slots are flush with the floor, well drained and run across in the direction of travel, hence they contribute to acoustic orientation. Tactile cues to navigate the space include building textures, which identify the old versus new components of the building and allow users to familiarise themselves with the material representing each area. The central community meeting space walls where the entrances to Studios 1 and 2 are located, are made of brick and dry wall, respectively, with the entry to Studio 3 located to one side of the café kitchen. Internal doors leading to the studios strongly contrast with the surrounding wall in colour and material.

All floor surfaces are level and flat without irregularities exceeding 5 mm, and made of firm materials that have adequate load-bearing capacity for persons using wheeled mobility devices. Both walls and floors have low reflective properties and are void of patterns. Vivid colours and bold patterns are avoided throughout the project. The stairs are located so that they are not in the direct line of travel. The location of accessible toilets is the same on both floors of the building. Opportunities to preview spaces are provided. The entrance doorway is glazed. All internal doors, except for those leading to toilets and changing rooms, include glazed panels (extending from 0.60 m to 1.70 m above floor level and 0.15 m wide), in order for users to verify whether they intend to enter the space beyond, especially during rehearsals and classes. The lift is glass-encased to support visual orientation.

The project has a website that provides information about how to get to the building, the internal plan and environment, facilities and provides a virtual tour via a video. Crowding is avoided via bookings.

B.5.2 score is evaluated for the building in Table 98 (corresponding to Excellent performance). Overall, the project meets the specifications of EN 17210 through compliance with TR 17621 requirements. The project meets most of the B.5.2 enhanced criteria. It does not meet the criteria for: signage LRV difference equal to or higher than 70 points, directional signage to be visible from all directions, height of public ICT screens, steps having 70 points LRV difference to the edge of the tread and riser. The project is not a complex visitor destination and is not expected to have crowding. These enhanced criteria are therefore not applicable.

Table 98. Example of B.5.2 evaluation.

Metric	**Score**	**Non-applicable**[1]
Select single value below:		
The project does not comply with the EN 17210 (CEN, 2021b) sections listed below.	x	
The project complies with the following EN 17210 sections:[2]	√ *Check next metrics.*	
6.1 Wayfinding, orientation and navigation		
6.2 Wayfinding information		
6.3.1-3 Wayfinding - visual contrast		
6.4 Tactile information		
6.5 Audible information and hearing enhancement		
6.6 Signage		
6.7 Graphical symbols		
9.1.3, 9.1.7, 9.1.9 Entrances		
9.2.3, 9.2.12–14 Corridors and passageways		☐
9.3.10 Doors		
9.6 Surface finishes and materials		
10.3.6–7 Handrails		
10.4.8 Lifts		☐
11.1.7–8 Service counters for information, ticketing and reception		☐
11.2.4–5 Waiting and queuing areas		☐
11.3.11 Seating and resting areas		☐
13.1 User interface, controls and switches – rationale		
13.2 Public ICT information screens		☐

13.3 ICT user interfaces		
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with wayfinding design criteria that are less stringent than TR 17621 (CEN, 2021c).	0	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent wayfinding design criteria.	+40	
The project also complies with the following enhanced design features (multiple selections allowed but a maximum score applies to each category):		
Category: Tactile information	(≤5) *category max score applies*	
The maximum size of a tactile map is 0.60 m high · 1.00 m wide.	+5	
The height of the relief of raised tactile letters, figures and graphical symbols is 1.00–1.50 mm.	+5	
Category: Signage and public ICT information screens	(≤15) *satisfied*	
Signs are separated from other notices and pictures to avoid a cluster of competing information.	+2.5	☐
Signage has both symbols and words (except for universally accepted or mandatory safety symbols or pictures), is concise and easy to interpret, and contrasts from the surface it is mounted on (light reflectance value (LRV) difference ≥ 70).	0	☐
Signage uses consistent terminology in the built environment, digitally, and in any other medium.	+5	☐
Directional signage is visible from all directions of approach, where practicable, and repeated at each decision and reassurance point.	0	☐
Location signs confirm arrival at destinations.	+5	☐
The position of ICT screens above head height are at a minimum height of 2.30 m.	0	☐
Category: Steps, stairs, lifts, vertical and inclined lifting platforms, escalators and moving walks	(≤10) *satisfied*	
Steps and escalators have a strong visual contrast (LRV difference ≥ 70 points) to the edge of the tread and riser.	0	☐
Bold or intense patterns are avoided on walkways or stairs.	+5	☐
Category: Wayfinding	(≤15) *category max score applies*	
Information and wayfinding are provided in at least two sensory formats, including visual, audible, and tactile.	+5	
Opportunities to preview spaces such as through glazing, from outside or within the building, are provided where appropriate.	+5	
Unique and highly visible features are positioned in strategic locations to assist in wayfinding.	+2.5	
In complex visitor destinations, help points are provided at key intervals.	+2.5	☒
Key amenities (e.g. WCs, baby change, tea points, first-aid, restorative rooms) are located consistently throughout the building so they are found in a similar position on all floors.	+5	
Category: Colours and patterns	(≤10) *category max score applies*	
Vivid colours are kept to a minimum (to avoid overwhelm), and if red is used, especially on a white background, it is used sparingly (red causes difficulties for some people).	+5	
Large areas (including floors) of highly contrasting geometric or repetitive patterns (LRV difference ≥ 30 points) and patterns in three dimensional forms (including shadow patterns) are avoided.	+5	
Visual contrast (LRV difference ≥ 15 points) between adjacent floor finishes is avoided, or one or more incremental bands that are ≥ 50mm deep are provided to create a graduated change between the two primary surfaces.	+5	
Category: Information	(≤5) *category max score applies*	
Pre-visit preview information provides information about the environment, what to expect during a visit, and journey information. Preview information is available before the visit (e.g. virtual flythrough videos, audio description, building plans) as well as upon arrival.	+5	☐
If crowds are inevitable at predictable times, these timings are publicised so that people can avoid them, alongside provision of well signposted restorative spaces.	+5	☒
Indicator score = Σ(metric scores)	**92.5**	

[1] If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score. If satisfied and non-applicable metrics result in a score higher than the maximum within a category, then the maximum score of the category is applied.

[2] If the section of EN 17210 does not apply to the project (i.e. non-applicable is selected), then as long as all other stated sections are complied with, then the project is deemed to be in compliance with EN 17210.

Source: JRC.

Usability and operation (B.5.3) is evaluated according to the metrics of Table 96.

Doors: The main entrance doors have an automatic opening mechanism, triggered by movement or by the pressing of a button. Internal doors have horizontal handles of 'D-lever' type, that are 20 mm in diameter, 80 mm long, and located at a height of 0.90 m from the floor and 30mm from the door edge. The inside faces of accessible toilet doors are equipped with horizontal grab bars. All internal doors, including those for WC and changing rooms have a maximum opening force of 20 N and include kick plates. All internal doors are self-closing and have 0.40 m height at the base of the push side of doors. Emergency exit doors are operated by a horizontal bar.

Windows: The position of the windows in the building is dictated by the original building design. The lower edge of all windows is 1.10 m from the floor, and they extend to 0.50 m from the ceiling height. In the renovation, the location of windows is considered in the space planning, and openable windows are provided at the ground floor in the 3 studios and in the reception area on either side of the main entrance. The pattern of windows is repeated on the first floor, and openable windows are available in the office space, storage rooms and technical studio. No windows are positioned in toilets, the café and central meeting area, changing rooms or stairwell. The windows are equipped with lever handles for manual opening and closing. Moreover, they can be opened through an automated system, with controls for each window placed at 1.00 m height adjacent to the windows and always at a distance more than 0.70 m from any corner.

Ramps, stairs and lifts: Two powder coated metal handrails are provided along the ramp providing access to the main entrance: one at a height of 0.60 m and the second at 0.90 m from the ramp surface. Similarly, nylon-sleeved steel tube handrails are provided at 0.60 m and 0.90 m above the pitch of the stair and surface of landing for the internal staircase. For both the ramp and staircase, the upper and lower handrails have circular profiles with a diameter of 40 mm and 30mm, respectively. Circular handrails with a diameter of 30 mm are provided at a height of 0.90 m, on two sides of the lift car. A tip-up seat is not provided in the car. Both the landing and car control devices are placed at a height of 0.90 m from the floor level and at a distance of 0.50 m away from any corner. Audio messages are provided in the car to inform users of floor level reached, door opening, and at landing to inform of car arrival. All audible messaging is reproduced via an induction loop system. The area of active part of push buttons in both landing and car is 500mm^2. Each push button has a diameter of 20 mm and operating force of 2.5 N. Visual contrast is provided between the push buttons, face plate and surroundings. Symbols are provided in relief and braille as an independent feature to tactile figures.

Furnishings: The seating area in the reception comprises 4 fixed seats with the following features: seat height of 0.42 m, seat depth of 0.40m, backrest height of 0.75 m from the floor and angled 100 degrees to the seat, armrests provided every two seats that are at a height of 0.25 m with no setback from the seat front. The edges of the seat, backrest and armrests are rounded. Along one side of the seats, there is a designated space for wheelchair users to stop. Along the other side of the seats there is a free area for assistance dogs. The number of seats in the reception area are deemed adequate for the space use, considering minimal queuing. Furniture in the central community meeting area comprises a range of seat sizes, heights and shapes, adequate for different users. The seats are lightweight and easy to move. Coffee tables are on castors (with brakes) and can be re-arranged freely. Seats in the office space have adjustable heights, inclinations and armrests. All desks have adjustable heights to allow use whilst seated or standing. Accessible lockers are provided in the changing rooms, but hand dryers and WC flushing system are normal and not low-noise ones. Power outlets are provided throughout the building, and mounted on walls at a height of 0.40 m. Drinking fountains are located in the community central meeting space at 0.70 m above floor level and use a lever-type tap system. Wall-mounted first-aid kits are also provided in the three studios, the reception area and office area. All staff is trained in first-aid administration.

Kitchen area and storage: The arrangement of the kitchen in the café considers users with wheelchairs. The kitchen is u-shaped, with work surfaces and appliances located on three sides, and a clear central space of 1.80m in diameter. A 0.60 m wide and a 1.50 m long clear space of counter (void of appliances or base units) with knee recess is provided. This is adjacent to the main kitchen appliances which have features to facilitate access by users on wheelchairs; for example, the refrigerator and freezer are fitted as separate units on a plinth of height of 0.20 m. Knee space is also provided directly below the hob and sink. The sink is shallow and has a lever-type tap and the hob is insulated below. A smooth transition is provided between the work surface, hob and drainer. Kitchen cupboard doors have a 90-degree opening. The storage rooms on the first floor allow access of wheelchairs.

Facilities for assistance dogs: Assistance dogs are welcomed in the building. A gated area, for them to stay when their owner uses the studios, is provided within the community meeting space, in a corner away from the café and visible by staff.

Fire extinguishers and alarms: Fire extinguishers and alarms are located in each large space/room in the building (i.e. reception area, community meeting area, studio rooms, office space). Fire extinguishers are mounted at a height of 0.80 m from the floor and are at least 0.60 m away from any corner. Fire alarms are placed near the fire extinguishers, at a height of 1.00 m from the floor level.

Sanitary accommodation: These are provided adjacent to the reception areas and in the changing room at the ground floor. Other (non-accessible) toilet facilities are also provided in the changing room. On the first floor, the plan location of the accessible toilets is the same as for the ground floor. All accessible toilets have 1.00 m width outward opening doors, with D-lever type door handle that also activates the locking mechanism (when pulled upwards), and horizontal pull handle. One of the accessible toilets in the lobby area is designated as a baby changing facility (and hence are larger, to accommodate a 0.50 m by 0.70 m foldable table, nappy bins and other accessories). Each accessible toilet is a corner-type toilet, with a clear manoeuvring space of at least 1.50 m in front of the toilet pan, and lateral, oblique and frontal space for transfer to toilet pan. The accessible toilets have a toilet seat height of 0.45 m and foldable grab rails at 0.65 m height from the floor (i.e. 0.20 m above the toilet seat level). These extend to 0.20 m in front of the toilet pan, have rounded edges and are able to withstand a force of 1.7 kN in any direction. The accessible toilets have a washbasin located at 0.55 m distance from the toilet seat. The washbasin provides a knee space height of 0.70 m above the floor surface and a knee depth of 0.30 m. The child accessible toilets have a toilet seat height of 0.32 m and foldable grab rails at 0.47 m height from the floor. These extend to 0.20 m in front of the toilet pan, have rounded edges and are able to withstand a force of 1.70 kN in any direction. All washbasins have lever-type tap controls. Separate changing room spaces are provided for male and female users, with a breast-feeding room located in the female changing room. The breast-feeding room contains a comfortable chair, one electrical outlet, a microwave for sterilisation, and a user-operated lock with occupancy indicator. The male and female changing rooms have a shower section. Each shower room section contains four separate showers, one of which is accessible. Eight showers are more than sufficient for a building maximum occupancy of 400 people according to WELL v2 (IWBI, 2020) V04 – Part 2. The accessible showers contain a foldable waterproof shower seat able to withstand a force of 1.70 kN in any direction, with fixed vertical and horizontal grab rails for transfer to seat, and clear manoeuvring space of 1.80 m in diameter. A space of 0.90 m width by 1.30 m depth is also provided alongside the seat.

All design features of the case study project meet the relevant specifications in TR 17621 but do not meet some of the enhanced criteria of B.5.3. The criteria for door opening force and for horizontal bars on wide doors are not achieved. In the latter case, although horizontal grab bars are provided in toilets, they are not on all internal doors (which all exceed 0.85 m in width). The enhanced criterion for handrails in lift cars is not met, nor are the criteria for the kitchen to have 180 degree opening cupboard doors and slide out shelves below the work surface. Minimum distance from control to internal corners is 0.60 m and not 0.70 m. Although all provided controls and switches are intuitive, no additional information is provided for their use. A space for practice of faith and/or contemplation is not provided. Sufficient shower facilities are provided to meet the requirements of WELL v2 (IWBI, 2020) C04 – Part 2. Although a separate breast-feeding room is provided, not all the amenities required by WELL v2 (IWBI, 2020) C09 to be within the breast-feeding room are provided. Hence, this metric is not satisfied. Although the central community meeting space provides an area for distraction and restoration, it only meets 4 of the 5 criteria in Part 1c of WELL v2 (IWBI, 2020) M07. Also, no restorative external space is provided. Hence, the project does not meet this enhanced requirement. The community centre is composed of large spaces but no specific smaller space for retreat is provided within any of these.

B.5.3 score is evaluated in Table 99 (corresponding to Good for this indicator). Addressing any of the design features that do not meet the enhanced criteria, as described above, could increase the score such that it would reach a higher performance class.

Table 99. Example of B.5.3 evaluation.

Metric	Score	Non-applicable[1]
Select single value below:		
The project does not comply with the EN 17210 (CEN, 2021b) sections listed below.	x	
The project complies with the following EN 17210 sections:[2]	√ *Check next metrics.*	
9.3.7–8, 9.3.12–14 Doors		
9.4.1–5 Windows		
10.3.5 Handrails		
10.4.5–6, 10.4.12 Lifts		☐
11.2.6 Waiting and queuing areas		☐
11.3.1–10, 11.3.12 Seating and resting areas		☐
11.4 Storage areas, lockers and baggage storage		☐
11.5 Kitchen areas and kitchenettes		☐
11.6 Facilities for assistance dogs		
12.1.1–7 Accessible toilets		
12.2 Toilets for general use		
12.3 Sanitary facilities for other users		
12.4 Showers and bathrooms		
13.4 User interface, controls and switches – controls and switches		
13.5 User interface, controls and switches – examples of general use elements		
Compliance with EN 17210 is demonstrated through (single selection allowed):		
Compliance is demonstrated through use of national guidance and regulations with usability and operation design criteria that are less stringent than TR 17621 (CEN, 2021c).	0	
Compliance is demonstrated through use of TR 17621, or national guidance and regulations with equally (or more) stringent usability and operation design criteria	+40	
The project also complies with the following enhanced design features (multiple selections allowed but a maximum score applies to each category):		
Category: Doors	(≤10) *satisfied*	
Operating force of maximum 15 N for manually operated doors without door closers.	0	
A horizontal supportive grab bar is provided for doors wider than 0.85 m and for the inside face of accessible toilet doors.	0	
All manually operated door opening hardware is lever action.	+2.5	☐
Category: Lifts	(≤5) *satisfied*	
Lift cars have a min of one handrail on each car wall, only interrupted by the operating panel, with the free space between the wall and the gripping part at least 50 mm.	0	☐
Category: Kitchen areas and kitchenettes	(≤5) *satisfied*	
Cupboard doors have a 180-degree opening.	0	☐
Pull-out shelves in kitchen areas and kitchenettes are fitted immediately below the work surface.	0	☐
Refrigerators and freezers are fitted as separate units on a plinth with a min. height of 0.20 m.	+2.5	☐
Category: User interface, controls and switches	(≤15) *satisfied*	
Where card slots are provided, they are between 0.80-0.90 m above floor.	+2.5	☒
Minimum distance from control to internal corners is 0.70 m.	0	
Height of controls above floor surface is between 0.80 m and 1.10 m.	+5	
Fixtures and controls are low noise where practicable (e.g. soft close cupboards and toilet lids, quiet flush WC systems). Where provided, quiet hand dryers (maximum 70 dB) are selected.	0	
Fittings, switches, controls and technology are intuitive and simple to use. Additional simple directions for use are provided.	0	
Category: Facilities	(≤20) *satisfied*	
WELL v2 (IWBI, 2020) V04 Facilities for Active occupants – Part 2 criteria are met.	+5	☐
WELL v2 (IWBI, 2020) C09 New mother support – Part 2 criteria are met.	0	
Sanitary facilities (including WCs, changing rooms and showers where provided) are ambulant-accessible, wheelchair-accessible (including wheelchair-accessible for children), and appropriate for use by obese and bariatric users.	+5	

There is provision for self-contained WCs (with sink inside and within reach from the toilet bowl), baby changing facilities (for all genders), and stoma management within WCs.	+5	
First aid/medical facilities and equipment are provided in sufficient quantities for the number of users.	+5	
Category: Restorative spaces	(≤10) *satisfied*	
WELL v2 (IWBI, 2020) M07 Restorative spaces criteria are met.	0	
Space(s) for practice of faith and/or contemplation are provided.	0	☐
Where a large space is provided, smaller areas within the space allow retreat, or variation in ceiling heights is provided, with lower ceiling creating a more intimate quiet space.	0	☐
Category: Furnishings	(≤5) *satisfied*	
A mix of furniture styles is used to meet a variety of user needs and settings. This includes ergonomic considerations, including sit-stand desks, and different seat heights and support features, giving people options and choices to find the most suitable solution for their requirements.	+5	
Indicator score = Σ(metric scores)	**77.5**	

1 If the non-applicable option is selected (when available), the full metric score is considered in the evaluation of the indicator score. If satisfied and non-applicable metrics result in a score higher than the maximum within a category, then the maximum score of the category is applied.

2 If the section of EN 17210 does not apply to the project (i.e. non-applicable is selected), then as long as all other stated sections are complied with, then the project is deemed to be in compliance with EN 17210.

Source: JRC.

Having evaluated the scores for each indicator, B.5 is calculated in Table 100, corresponding to an Excellent KPI performance class.

Table 100. Example of B.5 evaluation.

Indicator	**B.5.1**	**B.5.2**	**B.5.3**
Indicator score	100	92.5	77.5
Indicator performance class (indicative	(Excellent)[1]	(Excellent)[1]	(Good)[1]
B.5 score	= 0.33 · (100 + 92.5) + 0.34 · 77.5 = 89.9		
B.5 performance class	Excellent		
B.5. performance class score ($PCS_{B.5}$)	100		

1 Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

4.9 Maximising durability and service life (B.6)

4.9.1 Description and assessment

Under the KPI Maximising durability and service life (B.6), a quantitative assessment of the following indicators is provided:

- *Durability (B.6.1)*: Duration of the useful life of the main elements of the building, between necessary refurbishments or renewals.
- *Design for adaptability (B.6.2)*: Extent to which the design of the building allows and accommodates changing user needs and market conditions.
- *Design for deconstruction (B.6.3)*: Extent to which the design of the building facilitates the future disassembly, reuse and recycling of building elements, components, parts and materials.

B.6 score is evaluated according to Equation (161).

$$B.6 = \sum_{j=1}^{3}(w_{B.6.j} \cdot B.6.j) \Big/ \sum_{j=1}^{3}(w_{B.6.j}) = 0.3 \cdot B.6.1 + 0.4 \cdot B.6.2 + 0.3 \cdot B.6.3 \leq 100 \qquad (161)$$

In the above equation, indicators promote resource efficiency, by ensuring that the service life of elements, components, parts and materials is maximised (B.6.1) and likely extended beyond the useful life of the building (B.6.3) that, at the same time, is renewed, allowing accommodating substantial changes in user requirements and needs (B.6.2). The combined optimisation of these three indicators is essential, as poor performance of one indicator may undermine the efforts to maximise the others. Very durable products that are not easily adaptable to new uses and purposes could go out of fashion or become obsolete, due to user needs or market factors, leading to their disuse before the end of their service life. Similarly, durable products that are not designed for disassembly cannot be adequately reused in new buildings or efficiently recycled. Both scenarios result in unnecessary removal, disposal, new purchase and new construction, making an inefficient use of the energy invested into the long-lasting products.

Each indicator is evaluated with a score between 0-100. The performance class of the B.6 KPI is assessed according to the thresholds in Figure 74.

Figure 74. B.6 performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
B.6 thresholds ($t_{B.6}$):	0 ≤	$t_{B.6,\ Acceptable}$ ≥ 25	$t_{B.6,\ Good}$ ≥ 50	$t_{B.6,\ Excellent}$ ≥ 75	≤ 100

Source: JRC.

B.6 and its three indicators are designed to be implemented at the building scale, aggregating the assessment conducted over main spatial, architectural, structural, installation and service design features (B.6.1 and B.6.2) or its complete bill of quantities (BoQ) and materials (BoM) (B.6.3). To make and manage a harmonised estimate and classification of BoQ and BoM during the design stage, the Level(s) inventory template may be adopted (Donatello et al., 2021). B.6.1, B.6.2 and B.6.3 evaluation is affected by the project scale and type.

When a project, classified into the neighbourhood or urban scale, involves buildings with distinct design characteristics, thus likely leading to different indicator scores for each of them, the evaluation shall be carried out by identifying representative samples of buildings with similar design features. For each of these representative building designs, a separate assessment should be performed. The overall score per indicator is then estimated as a weighted average of the separate assessment scores, with the weights obtained from the relative occurrence of each building design.

For renovation projects, the assessment of B.6.1 and B.6.2 focuses on the specific aspects of the building and spaces that are affected by the proposed renovation works. However, when these indicators and/or any of their metrics address an aspect that has not been altered by the renovation, they are assessed considering the as-built state (i.e. condition existing before renovation and still present in the building), as this determines the service life of the building and its elements. The evaluation of B.6.3, instead, should be focused on the complete BoQ and BoM of the elements, components, parts and materials added during the renovation works.

The evaluation of the indicators is conducted by the design team, comprising architects, structural engineers and service engineers, likely seeking the advice of product manufacturers (B.6.1 and B.6.3), property market experts (B.6.2), demolition contractors and waste management experts (B.6.3), energy/sustainability consultants to conduct a life cycle analysis (LCA) or a global-warming potential (GWP) assessment, or experts familiar with the concept of buildings as material banks (BAMB) (Dodd et al., 2021c, d).

The assessment requires the identification and collection of the building design plans, architectural and structural design drawings, service plans, BoQ and BoM for the whole building or the renovated section of the building.

4.9.2 Durability (B.6.1)

The Durability indicator is evaluated through a dimensionless score. In the absence of a European standardised method, an approach based on the CASBEE property appraisal framework (IBEC, 2014) is adopted in the NEB self-assessment method. B.6.1 measures the capability of the building to maximise the interval between refurbishments and renewals. The durability score varies between 0 and 100 and is calculated as the weighted sum of the scores for the expected service life of main building elements including structural materials, interior and exterior finishes, specific building systems (HVAC, water supply and drainage pipe), and major equipment and services. Equal weights are adopted. The scores for the considered building components are reported in Table 101, and are assigned according to the following rationale:

- Low service life of elements – metric score = 0.
- Acceptable service life of elements – metric score = 33.

— Good service life of elements – metric score = 67.

— Excellent service life of elements – metric score = 100.

Table 101. B.6.1 score.

Metric	**Score**	**Weight (w)**
Service life of structural materials (single selection allowed):		
< 20 years 20 – < 40 years 40 – < 70 years ≥ 70 years	0 33 67 100	0.2
Service life of exterior finishes (single selection allowed):		
< 10 years 10 – < 20 years 20 – < 30 years ≥ 30 years	0 33 67 100	0.2
If [non-residential project type] has been selected, service life of interior finishes (single selection allowed):		
< 5 years 5 – < 10 years 10 – < 20 years ≥ 20 years	0 33 67 100	0.2
If [residential project type] has been selected, service life of interior finishes (single selection allowed):		
< 10 years 10 – < 15 years 15 – < 25 years ≥ 25 years	0 33 67 100	0.2
Select single value below:		
Heating, ventilation, and air conditioning (HVAC) system is present. HVAC system is not present.	*Check next metrics.* *Check next metrics.*	
If [HVAC systems is present], service life of HVAC, water supply and drainage pipe systems (single selection allowed):		
None of the following. Top three most used pipe system types (in terms of weight) > 20 years. At least two out of the top three most used pipe system types (in terms of weight) > 30 years. At least two out of the top three most used pipe system types (in terms of weight) > 40 years **and** none < 20 years.	0 33 67 100	0.2
If [HVAC systems is not present], service life of water supply and drainage pipe systems (single selection allowed):		
None of the following. Top two most used pipe system types (in terms of weight) > 20 years. At least one out of the top two most used pipe system types (in terms of weight) > 30 years. At least one out of the top two most used pipe system types (in terms of weight) > 40 years **and** none < 20 years.	0 33 67 100	0.2
Service life of major equipment and services (single selection allowed):		
< 7 years 7 – < 15 years 15 – < 30 years > 30 years	0 33 67 100	0.2
Indicator score = Σ(metric score · weight)	**≤ 100**	

Source: JRC.

Whenever more types of structural materials are present and/or the structural elements face different exposure conditions, the evaluation should be based on the element with shortest service life among those with a share higher than 25% of the total amount of structural materials (either in terms of area or cost). The same applies to internal and external finishes.

For HVAC, water supply and drainage, the assessment focuses on the three pipe system types with the largest total weight of pipes in the building. Each type is characterised by a specific use (i.e. hot, cooling, mixed water, air, oil, etc.), material and jointing method. When pipes are used for water supply and drainage only, with no HVAC system present, the assessment focuses on the two most used pipe system types.

Finally, major equipment and services refer to systems that ensure operationality and liveability in buildings (i.e. generators, boilers, chillers, air conditioners, water tanks, pumps, etc.). The assessment should focus on the devices most extensively used for each main service equipment, based on the number of units and equipment capacity. The final score corresponds to the device with the lowest service life and a cost higher than 25% of the total cost of major equipment and services.

The service life of the main building elements, to be compared against the thresholds of Table 101, shall be determined according to well-established sources and methods such as the factor methodology, defined in ISO 15686-8 (ISO, 2008), accounting for the anticipated building life cycle and the specific operational and environmental conditions of each assessed element that are expected to alter the deterioration rate during its lifespan (IBEC, 2014). Reference service lifespan values are reported by relevant sources such as the Level(s) indicator 1.2 (Dodd et al., 2021b) and the Appendix 1 of the CASBEE manual (IBEC, 2014). The estimation can be supported by specific standards and codes, such as the EN 15459-1 (CEN, 2017) for heating systems, and information provided by manufacturers and suppliers (Dodd et al., 2021b).

Figure 75 shows indicator thresholds adopted to associate the indicator score to an indicator performance class. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 75. B.6.1 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.6.1 thresholds ($t_{B.6.1}$):	0 ≤		$t_{B.6.1,\ Acceptable}$ ≥ 25		$t_{B.6.1,\ Good}$ ≥ 50		$t_{B.6.1,\ Excellent}$ ≥ 75		≤ 100

Source: JRC.

4.9.3 Design for adaptability (B.6.2)

The design for adaptability and renovation indicator is evaluated through a dimensionless score based on Level(s) indicator 2.3 (Dodd et al., 2021c). The indicator measures the readiness of a building for adaptation to substantial changes, induced in the medium to long term by demographics, social, economic, technological and physical surrounding conditions (ISO, 2020), such as demand in the property market, existing and future user needs and life changes (Dodd et al., 2021c). The aim is to ensure adequate load capacity and space to accommodate the new functions (IBEC, 2014). The adaptability score varies between 0 and 100 and is the sum of the weighted scores for each adaptability aspect incorporated into the building design (Dodd et al., 2021c). The scores and the aspects that are targeted by B.6.2 are reported in Table 102, where the metric scores are assigned according to the following rationale:

— Changing building use and equipment is extremely difficult – metric score = 0.

— Changing building use and equipment is moderately difficult – metric score = 1.

— Changing building use and equipment is relatively easy – metric score = 2.

— Changing building use and equipment is extremely easy – metric score = 3.

Most of the scores and weights reported in Table 102 were originally proposed for the design of office buildings. In the absence of a standardised alternative method, the values are considered in the NEB self-assessment method as applicable to both residential and non-residential (commercial) buildings. Regarding the 'higher ceilings for service routes' aspect, the specific metric score values included in Table 102 for residential buildings are based on values recommended by the building flexibility calculator and the adaptive capacity calculation tool, provided by BREEAM Netherlands (Dutch Green Building Council, 2023). The same sources are used to implement minor amendments to the original Level(s) indicator 2.3 table (Dodd et al., 2021c).

Table 102. B.6.2 score.

Metric	Score	Weight (w)
Changes to the internal space distribution:		
Column grid spans: Minimum spacing of vertical load-bearing elements (single selection allowed):		
< 5400 mm	0	0.04
5400 – < 8100 mm	33	
≥ 8100 mm	67	
free span	100	
Façade pattern: Spacing between openings (single selection allowed):		
≥ 1800 mm	0	0.04
1350 – < 1800 mm	33	
1350 – < 1800 mm, some openings 900 – < 1350 mm	67	
900 – < 1350 mm, some openings < 900 mm	100	
Internal wall system (single selection allowed):		
Immovable interior walls, multiple functions (more than 20% of the walls in linear metres are load bearing).	0	0.14
Immovable interior walls, non-permanent (non-load bearing).	33	
Movable interior walls, require disassembly.	67	
Easily movable interior walls, partition system.	100	
Unit size and access: Average portion of floor area that can be used separately from other spaces (single selection allowed):		
≥ 600 m^2	0	0.10
400 – < 600 m^2	33	
200 – < 400 m^2	67	
< 200 m^2	100	
Changes to the building services:		
Ease of access to service ducts: Location of key service ducts (single selection allowed):		
Embedded in the floor.	0	0.04
Between 2 building layers.	33	
Above one building layer (floor), exposed or easily removable cover.	67	
Below one building layer (ceiling), exposed or easily removable cover.	100	
Ease of access to plantrooms (single selection allowed):		
Embedded in a sub-basement of the building.	0	0.04
Located on the roof or within an accessible patio.	33	
Located on the ground floor with easy external access.	67	
Located external to the building with complete access.	100	
Longitudinal ducts for service routes (single selection allowed):		
Connection grid in 1 direction	0	0.04
Cable duct in 1 direction	33	
Connection grid in 2 directions	67	
Cable duct in 2 directions	100	
Higher ceilings for service routes: If [**non-residential project type**] has been selected, internal height (floor surface to structural surface for at least 95% of the floor area) (single selection allowed):		
< 3000 mm	0	0.14
3000 – < 3500 mm	33	
3500 – < 4000 mm	67	
≥ 4000 mm	100	
Higher ceilings for service routes: If [**residential project type**] has been selected, internal height (floor surface to structural surface for at least 95% of the floor area) (single selection allowed):		
< 2600 mm	0	0.14
2600 – < 3000 mm	33	
3000 – < 3400 mm	67	
≥ 3400 mm	100	
Services to sub-divisions: Average portion of floor area that can be serviced by a sanitary facility (single selection allowed):		
≥ 600 m^2	0	0.10
400 – < 600 m^2	33	
200 – < 400 m^2	67	
< 200 m^2	100	
Changes to the building façade and structure:		

Façades (single selection allowed):		
Bearing façade with bearing obstacles[1] Bearing façade, no bearing obstacles[1] Non-bearing façade with bearing obstacles[1] Non-bearing façade, no bearing obstacles[1]	0 33 67 100	0.14
Futureproofing of load bearing capacity of floors: Imposed loads (at least for 75% of the floor area): (single selection allowed):		
2.00 kN/m^2 3.00 kN/m^2 4.00 kN/m^2 5.00 kN/m^2	0 33 67 100	0.14
Structural design to support future expansion: Capacity to add storeys (single selection allowed):		
1 storey 2 storeys 3 storeys 4 or more storeys	0 33 67 100	0.04
Indicator score = Σ(metric score · weight)	**≤ 100**	

[1] Examples of obstacles include bearing interior walls, columns, elevator shafts or installation ducts.

Source: Adapted from Dodd et al. (2021c) and (Dutch Green Building Council (2023).

The adaptability of the building project to accommodate variations in demands and uses is evaluated across three main categories of design concepts: (*i*) internal space distribution; (*ii*) building servicing; (*iii*) building façade and structure.

The organisation of internal space influences the flexibility for reconfiguring interiors as the needs of users change. Vertical load bearing elements and non-structural walls may limit the viable layouts and uses. In particular, greater spacing between vertical load-bearing elements allows for an open-plan design, providing maximum flexibility for reconfiguring spaces. Similarly, walls designed to be demountable or movable, without affecting the structural integrity or interfering with service ducts, can significantly increase the adaptability, as they can easily accommodate new layouts. If more than 20% of the walls (in linear metres) are load bearing, walls should be considered as 'immovable and multiple functions'. Non-permanent walls are non-load bearing. Walls are movable if they can be placed in another location without material losses and fulfilling the same functions (W/E Adviseurs and Dutch Green Building Council, n.d.). Narrower façade bays contribute by creating smaller, more manageable sections of the façade, which can be more easily modified or replaced independently of the rest of the building, and by supporting the rearrangement of rooms number, sizes and functions. Multiple access points enhance adaptability by allowing different areas to be used independently or in various configurations. This is particularly important for buildings that may be subdivided or repurposed. This aspect is evaluated through the average area of the units, namely portions of the floor area with their own entrance and whose space can be used separately from the others (W/E Adviseurs and Dutch Green Building Council, n.d.).

Regarding adaptability aspects relevant to service ducts, the assessment should focus on system parts which support and provide the main functions required for each building use, namely the main parts of air conditioning pipes, the main sections of the building plumbing and wiring system, and the main sections of the building communication cables.

The ease of replacing and reorganising service and equipment is a critical aspect of adaptability in building design. It is essential to position key service ducts in locations that are accessible without causing damage to surrounding building components. Placing them above or below elements such as false ceilings or raised floors or in exposed areas facilitates maintenance, upgrade, or replacement operations with respect to embedded solutions. However, false ceilings and raised floors that are closed and non-accessible for inspections require intrusive operations to allow replacement and reorganisation of the service, including demolition and reconstruction, potentially damaging the surrounding elements. In this case the ducts are considered as located between two building layers and a limited improvement to adaptability is obtained. Ducts in exposed areas or covered by easily removable floors and ceilings (e.g., suspended tiles and metal framework, or lamellar ceilings) allow higher adaptability. Additionally, having greater internal height in a building to accommodate service routes further enhance adaptability. In the assessment this is calculated as the clear height from the top of the finished floor surface to the bottom of the lowest structural section. The maximum value representative of at least 95% of the floor area should be considered (W/E Adviseurs and Dutch Green Building Council, n.d.). Similarly, the location and accessibility of plantrooms are crucial for streamlining alterations to mechanical and electrical equipment. Longitudinal ducts for service routes, facilitating the distribution from central sources to different building areas, offer more flexibility in the placement of service points compared to connection grids in which connections are at fixed locations. This longitudinal ducts or connection grid can be distributed along a single direction, i.e. within a wall. However, the flexibility further benefits from distributions occurring in two directions. Regarding sanitary facilities, accommodating future subdivisions is facilitated by having a larger number of individual servicing points. This aspect is evaluated by considering the average portion of floor area served by each sanitary facility.

Ultimately, adaptability is significantly impacted by the structural capacity of load-bearing elements. On one hand, any proposed new use or alteration to the horizontal or vertical layout is constrained by the structure ability to support increased loads. In particular, structural floor systems must present an adequate load bearing capacity, at least for 75% of the total floor area, for anticipated changes in live loads, due to repurposing. Whereas actual load-bearing elements must support future additions of storeys. On the other hand, the presence of load-bearing elements within or interacting with the façade restricts the permissible alterations and reorganisations of both internal room subdivisions and external façade patterns.

Figure 76 shows indicator thresholds adopted to associate the indicator score to an indicator performance class. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 76. B.6.2 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
B.6.2 thresholds ($t_{B.6.2}$):	$0 \leq$	$t_{B.6.2, Acceptable} \geq 25$	$t_{B.6.2, Good} \geq 50$	$t_{B.6.2, Excellent} \geq 75$	≤ 100

Source: JRC.

4.9.4 Design for deconstruction (B.6.3)

The Design for deconstruction indicator is quantitatively evaluated through a dimensionless score originally developed as Level(s) indicator 2.4 (Dodd et al., 2021d). The indicator varies between 0 and 100, for increasing ease of disassembly and extent of reuse, and may be weighted by mass, by volume or by value of the applicable elements (components, parts and materials). Mass is considered as a convenient common unit to compare distinct building elements, as it is expected to be easily estimated even when these products are supplied in units other than mass. To prevent an excessive influence of heavier products on the final score, the overall score may be weighted by volume or by economic value. In this case, cost should be specific to the building elements (components, parts and materials), excluding any labour or installation (Dodd et al., 2021d).

The spreadsheet calculator of the Level(s) indicator 2.4 may be used to identify the relevant building elements (Table 103). Subsequently, for each element the respective mass, volume or economic value should be estimated.

Table 103. Taxonomy of building elements.

Tier 1	Tier 2	Tier 3 (building elements)	Tier 4 (components, parts, materials)
Shell	Foundations (substructure)	Piles and shallow foundations	For piles: e.g. load-bearing piles, end-bearing piles, friction piles, pile caps and ground anchors. For shallow foundations: e.g., strip, trench-fill, rubble trench or raft foundations
		Basements	e.g. waterproofing, masonry blocks, precast concrete modules, reinforced concrete, insulation.
		Retaining walls	e.g. sheet piles or diaphragm walls.
	Loadbearing structural frame	Frame (beams, columns and slabs)	e.g. all loadbearing elements appearing in the superstructure (above ground structure).
		Upper floors	e.g. coverings on floors, including screeds, damp-proof courses, insulating and protective layers, wearing surfaces, false floors for services and floating floors.
		External walls	e.g. components used for building the wall, whether it is loadbearing or non-loadbearing. Also covers parapets, infillings, protective treatments, insulation and connections to other building elements.
		Balconies	e.g. balcony wall, glazing, privacy screens etc.

	Non-load bearing elements	Ground floor slab	e.g. reinforcement, concrete, connections to structural columns, surface treatments for waterproofing.
		Internal walls, partitions and doors	e.g. infills, precast wall units, window frames, windows, door frames, doors, locking mechanisms, toilet cubicles or partitions and any plaster rendering, cladding, sealing, insulation or protective layers.
		Stairs and ramps	e.g. structural material plus any physical support rails for users and connections.
	Façades	External wall systems, cladding and shading devices	e.g. external cladding, including renders, damp-proofing, insulation and protective layers.
		Façade openings (including windows and external doors)	e.g. lintels, window frames, door frames, windows, doors, locking mechanisms, shutters, window sills, fittings and ventilation components.
		External paints, coatings and renders	
	Roof	Structure	e.g. standard structural elements such as wall plates, rafters, joists, gable walls, purlins, trusses, connectors, any connected overhanging canopies, roof slab, blue roofs (designed to hold rainwater on roof); green roofs (designed for vegetation).
		Weatherproofing	e.g. roof coverings such as plain tiles, interlocking tiles, slates, insulation, sealing and waterproofing treatments.
	Parking facilities	Above ground and underground (within the curtilage of the building and servicing the building users)	e.g. flooring, surface treatments, floor/wall markings, access barriers etc.
Core	Fittings and furnishings	Sanitary fittings	e.g. sanitaryware such as WC bowls, cisterns, urinals, bidets, washbasins, sinks, showers, bathtubs.
		Cupboards, wardrobes and worktops (where provided in residential property)	(Mostly relevant to residential buildings) e.g. cupboard units, wardrobes, worktops, handles, panels, shelves and sealants.
		Ceilings	e.g. ceiling lining, including plaster rendering, insulation, protective layers or acoustic materials associated with tightly-attached or suspended ceilings.
		Wall and ceiling finishes	e.g. paints, varnishes or plaster rendering.
		Floor coverings and finishes	e.g. covering materials and associated underlays, damp-proof courses, insulation, grout, binders and coatings applied to floating floor or raised floor surfaces. Skirting boards at wall edges is also included here.
	In-built lighting system	Light fittings	e.g. fixed lights or lighting units comprising one or more lamps and associated control gear (not including the light switch and wiring to the lighting unit).
		Control systems and sensors	e.g. building automation and control for aspects such as CO2 concentration controlling ventilation equipment for maintaining indoor air quality or temperature controlling heating/cooling system for maintaining thermal comfort.
	Energy system	Heating plant and distribution	e.g. boilers, heat pumps, (combined heat and power plants are counted under “electricity generation”) heat exchangers, connectors, radiators and distribution piping and ductwork.
		Cooling plant and distribution	e.g. air conditioning units, fans, reversible heat pumps, dehumidification equipment, connectors and ductwork.
		Electricity generation and distribution	e.g. photovoltaic, wind turbines or combined heat and power plant for onsite generation. Also including cabling from the local substation to the building junction box and cabling and switchgear, safety devices and circuits throughout the building to each plug socket.
	Ventilation system	Air handling units	e.g. equipment dedicated to mechanical ventilation, including ductwork. Any units responsible for heat recovery in ventilated air should be counted under heating plant and distribution.
		Ductwork and distribution	e.g. ductwork and distribution for heating plant, cooling plant and mechanical or passive ventilation.
	Sanitary systems	Cold water distribution	Piping, connections and fittings from the mains water inlet to sanitary devices throughout the building. Includes any equipment and parts for the collection, storage and distribution of collected rainwater or greywater.

		Hot water distribution	e.g. piping, connections and fittings that transfer hot water from heating plant to sanitary devices (hot water taps and shower).
		Water treatment systems	e.g. first flush diverters for collected rainwater or filters for collected greywater and rainwater.
		Building drainage system	e.g. pipes, fittings and storage tanks for the drainage of greywater or blackwater from sanitary devices, roof guttering and drainage and drainage from impermeable ground on the plot.
	Other systems	Lifts and escalators	e.g. motors, escalator handrails, lift compartment, interior lift cladding, escalator side panelling etc.
		Firefighting installations	e.g. sprinkler piping network, water tank, spray units, booster pumps etc.
		Communication and security installations	e.g. closed circuit TV network, cameras, data recording and storage devices, alarm systems, cabling and sensors.
		Telecoms and data installations	e.g. cabling, wi-fi routers, servers and ancillary equipment for and onsite data centres.
External works	Utilities	Connections and diversions	e.g. to mains water line, to local sub-station for electricity supply etc.
		Substations and equipment	e.g. control panels, fuses, transformers, trip switches and possible.
	Landscaping	Paving and other hard surfacing	e.g. tiles, flagstones, blocks and kerbstones made of natural stone, fired clay or precast concrete.
		Fencing, railings and walls	e.g. iron grated railings, fencing posts, brick walls, plastic coated metal wire fencing etc.
		Drainage system	e.g. to mains sewerage network or alternative drainage routes via sustainable drainage infrastructure installed onsite and possibly near site as well.

Source: Dodd et al. (2021d).

For each building element (components, parts and materials), the best practical outcome at the end-of-life (i.e. disposal, recovery, recycle, reuse) must be identified. B.6.3 score is calculated as the ratio of the actual quantity of deconstructed elements (Q_{dec}) to their total quantity (Q_{total}), measured by mass (kg), volume (m^3) or by economic value (Euro).

$$B.6.3 = \frac{Q_{dec}}{Q_{total}} \cdot 100 \tag{162}$$

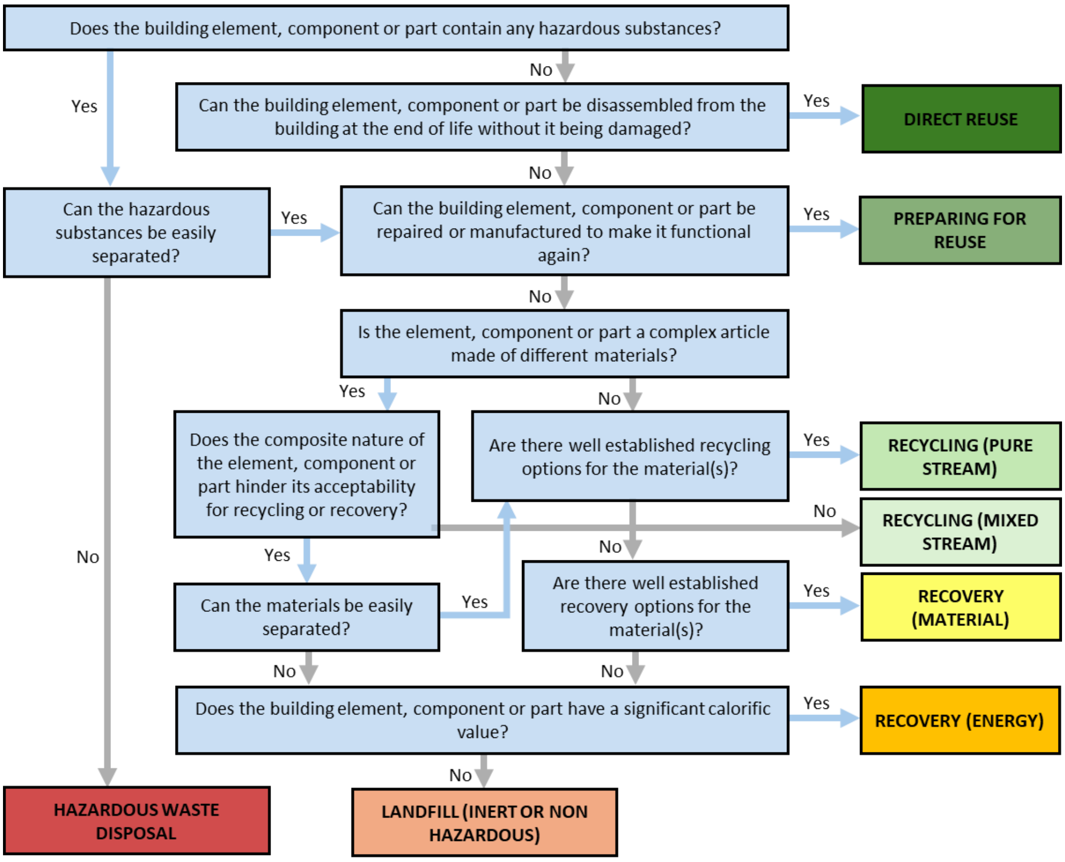
$$Q_{dec} = \sum_{i=1}^{n} (Q_i \cdot c_i) \tag{163}$$

$$Q_{total} = \sum_{i=1}^{n} Q_i \tag{164}$$

Q_i and c_i are the quantity and the circularity coefficient of the *i*-th product, respectively, out of the *n* forming the whole building. The circularity coefficient varies from 0 to 1, depending on the outcomes defined in the hierarchy of the Directive on waste (Directive, 2008; Dodd et al., 2021d), presented in Figure 77. The circularity coefficients associated with the outcomes are provided in Table 104.

B.6.3 score can be further broken down to scores corresponding to specific elements, as a means to identify weak building elements in terms of deconstruction.

Figure 77. Logic process for the assignment of circularity coefficient and waste hierarchy.



Source: Dodd et al. (2021d).

Table 104. Circularity coefficient.

Waste hierarchy	Hazardous waste disposal	Inert or non-hazardous landfill	Energy recovery	Material recovery	Mixed stream recycling	Pure stream recycling	Preparing for reuse	Direct reuse
Circularity coefficient (c_i)	0.00	0.01	0.15	0.25	0.50	0.75	0.90	1.00

Source: Dodd et al. (2021d).

Recommended performance thresholds for B.6.3 indicator and the minimum percentage of materials that should be directed to a specific end-of-life outcome are found in international and national standards and well-established certification schemes. Although a B.6.3 score equal to 100 is potentially achievable especially for buildings with limited service life, requiring full reusability is often impractical as some components may be obsolete by the time of the deconstruction (ISO, 2020). According to the European Directive on waste (Directive, 2008), at least 70% (by weight) of the non-hazardous construction and demolition waste (excluding naturally occurring material) generated on the construction site shall be prepared for reuse, recycling and other material recovery.

Design for deconstruction has been adopted by the Italian Minimum Environmental Criteria (CAM), made mandatory by the 'Procurement Code' (Decree, 2023). CAM includes an award for tenderers that adopt services designed to be fully disassembled, reused and/or recycled at the end-of-life (Decree, 2022). The Italian sustainability rating system, ITACA protocol, and the related UNI/PdR 13 (UNI, 2019) standard defines four increasing levels of performance in terms of design of disassembly with thresholds equal to 50, 65 and 80% in weight of shell elements (i.e. load-bearing and non-load-bearing elements, façades, and roof) designed to ensure ease of disassembly for reuse or recycle. Recently, the assessment method has been updated to UNI (2023). The LEED v4 certification scheme (USGBC, 2019) sets two increasing levels. The lower requires 50% of the total construction and demolition material diverted away from disposal towards higher outcomes of the waste hierarchy, including at least three material streams (such as concrete, wood, metal, plastic or glass), including complete cycles of collection, sorting and reprocessing into new products. The higher requires 75% of material diverted including at least four material streams. Another example is the Vancouver Green Demolition by-law (Council of the City of Vancouver, 2023), which requires that any authorised demolition of a residential building constructed in whole or in part before 1950 should result in the reuse or recycling of not less than 75–90% (in terms of weight) of all building non-hazardous materials.

Figure 78 shows indicator thresholds adopted to associate the indicator score to an indicator performance class in the case of B.6.3, considering the above sources. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 78. B.6.3 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.6.3 thresholds ($t_{B.6.3}$):	$0 \leq$		$t_{B.6.3,\,Acceptable} \geq 20$		$t_{B.6.3,\,Good} \geq 50$		$t_{B.6.3,\,Excellent} \geq 75$		≤ 100

Source: JRC.

4.9.5 Example (B.6)

In the following example a newbuild project type for non-residential main use is considered. The assessment is carried out at the building scale and no listed cultural heritage is affected by the project. All upper levels of a six-storey office building consist of external cross laminated timber (CLT) walls and slabs combined with an internal timber pillar and beam structure. The ground storey consists of reinforced concrete walls and foundations. The wooden exterior cladding is connected to sawn timber battens that create a ventilated cavity. Wood fibre insulation is used for the vertical walls, while mineral wool is used for the roof. To ensure fire-safety, most of the panels are covered by gypsum plasterboard.

Starting from B.6.1 and the assessment of the durability of structural materials, the factor method in ISO 15686-8 (ISO, 2008) is employed for timber (Table 105), considering a reference service life of 50 years and a normal quality of components, indoor and outdoor environment, in-use conditions and maintenance level factors. The project is characterised by a high quality of design and work execution, especially in the planning of processes and detailing of elements, ensuring that the timber is well-protected from the outdoor environment and moisture throughout all phases of its life cycle, including construction. Therefore, a value of 1.2 is assigned to the quality of design and the quality of work execution factors, while a value of 1.0 is considered for the other factors, resulting in an estimated service life of 72 years.

Table 105. Application of the factor method to estimate service life of elements.

Element	**Timber**	**Exterior cladding**
Reference service life (years)	50	35
Quality of components	1.0	1.0
Design level	1.2	1.0
Work execution level	1.2	1.0
Indoor environment	1.0	1.0
Outdoor environment	1.0	0.8
In-use conditions	1.0	1.0
Maintenance level	1.0	1.0
Estimated service life (years)	**72**	**28**

Source: JRC.

For reinforced concrete, the possible degradation mechanisms are identified based on the class of exposure. Mix design and detail specifications are defined to ensure avoidance of these mechanisms; moreover, a full probabilistic estimation of chloride-induced corrosion is conducted, resulting in less than 10% probability of corrosion initiation within 100 years, which is assumed as the estimated service life.

Given that both materials account for more than 25% of the structure costs, they are both considered in the assessment. The first metric of B.6.1 indicator (i.e. service life of structural materials in Table 101) depends on the one with the shortest service life, namely timber, scoring 100 (Table 106).

The main exterior finishes consist of timber cladding elements. To estimate their service life, the factor method (ISO, 2008) is employed, considering a reference service life of 35 years (Table 105). Due to the expected weathering, especially for the walls characterised by the worst exposure, a poor level for the outdoor environment factor is considered, with a value of 0.8, while normal conditions are considered for the remaining factors. The estimated service life is thus reduced to 28 years, resulting in a score of 67 for the second metric of the B.6.1 indicator (i.e. service life of exterior finishes) in Table 106.

The main interior finishes are composed of plasterboards, for which an estimated service life of 30 years is considered, resulting in a score of 100 for the third metric of B.6.1 (i.e. service life of interior finishes).

Service ducts comprise different materials and jointing methods. The three most used types in the building are copper (hot water), PVC (water supply, sewage and ventilation) and aluminium (rainwater drainage). All of them have an estimated service life between 30 and 40 years, corresponding to a score of 67 for the metric of service life of HVAC, water supply and drainage pipe systems.

Finally, major electrical and mechanical equipment has an estimated service life of 15 to 30 years, resulting in a score of 67 for the last metric of Table 106.

The above result in B.6.1 score equal to 80.2 (corresponding to Excellent performance).

Table 106. Example of B.6.1 evaluation.

Metric	**Score**	**Weight (w)**
Service life of structural materials (single selection allowed):		
≥ 70 years	100	0.2
Service life of exterior finishes (single selection allowed):		
20 – < 30 years	67	0.2
If [non-residential project type] has been selected, service life of interior finishes (single selection allowed):		
≥ 20 years	100	0.2
Select single value below:		
Heating, ventilation, and air conditioning (HVAC) system is present. HVAC system is not present.	√ *Check next metrics.* *x*	
If [HVAC systems is present], service life of HVAC, water supply and drainage pipe systems (single selection allowed):		
At least two out of the top three most used pipe system types (in terms of weight) > 30 years.	67	0.2
Service life of major equipment and services (single selection allowed):		
15 – < 30 years	67	0.2
Indicator score = Σ(metric score · weight)	**80.2**	

Source: JRC.

Regarding the evaluation of the adaptability indicator (Table 107), limited changes to the internal space distribution are allowed. In particular, columns have a minimum spacing of 5.5 m. Walls are non-load bearing and movable but require disassembly. Additionally, a large spacing between openings, approximately 1.9 m is designed. Several accesses to the building are defined and, at each floor, rooms and spaces can be organised in independent units of about 190 m^2 on average.

The design allows moderate changes to the building services. The service ducts are located below the ceiling and left exposed, allowing complete accessibility and high flexibility. Plant rooms are located at the ground floor with easy external access and longitudinal cable ducts are deployed in one direction. Internal height is slightly larger than 3.0 m. Individual servicing for sanitary facilities is possible for subdivisions of spaces, on average equal to 380 m^2, as two independent units are served by the same facility.

Finally, limited changes are allowed to the structure. The building features load bearing façades with obstacles. A redundant load-bearing capacity of slabs equal to 2.5 kN/m^2 is estimated and the structural design allows an expansion of 2 storeys. This corresponds to an overall value of B.6.2 equal to 41.3 (corresponding to Acceptable performance).

Table 107. Example of B.6.2 evaluation.

Metric	Score	Weight (w)
Changes to the internal space distribution:		
Column grid spans: Minimum spacing of vertical load-bearing elements (single selection allowed):		
5400 – < 8100 mm	33	0.04
Façade pattern: Spacing between openings (single selection allowed):		
≥ 1800 mm	0	0.04
Internal wall system (single selection allowed):		
Movable interior walls, require disassembly.	67	0.14
Unit size and access: Average portion of floor area that can be used separately from other spaces (single selection allowed):		
< 200 m^2	100	0.10
Changes to the building services:		
Ease of access to service ducts: Location of key service ducts (single selection allowed):		
Below one building layer (ceiling), exposed or easily removable cover.	100	0.04
Ease of access to plantrooms (single selection allowed):		
Located on the ground floor with easy external access.	67	0.04
Longitudinal ducts for service routes (single selection allowed):		
Cable duct in 1 direction	33	0.04
Higher ceilings for service routes: If [**non-residential project type**] has been selected, internal height (floor surface to structural surface for at least 95% of the floor area) (single selection allowed):		
3000 – < 3500 mm	33	0.14
Services to sub-divisions: Average portion of floor area that can be serviced by a sanitary facility (single selection allowed):		
200 – < 400 m^2	67	0.10
Changes to the building façade and structure:		
Façades (single selection allowed):		
Bearing façade with bearing obstacles[1]	0	0.14
Futureproofing of load bearing capacity of floors: Imposed loads (at least for 75% of the floor area): (single selection allowed):		
2.00 kN/m^2	0	0.14
Structural design to support future expansion: Capacity to add storeys (single selection allowed):		
2 storeys	33	0.04
Indicator score = Σ(metric score · weight)	**41.3**	

1 Examples of obstacles include bearing interior walls, columns, elevator shafts or installation ducts.

Source: JRC.

Finally, regarding B.6.3, design for deconstruction principles are well integrated into the project. Considering the whole building, wood materials comprise 44% of the full weight. 75% of wood materials are designed to be directly reused (e.g. most of wall and floor panels are designed to be disassembled with a minimum loss of material due to the removal of the connectors). The remaining 25%, which are expected to be unusable at the end of its life, are allocated for energy recovery. 36% of the building weight is composed of reinforced concrete, ceramic and natural stones and 11% in weight is gypsum. All these materials are designated for mixed stream recycling. Glass and other metal (such as windows, connectors, etc.) account for 6.5% of the building weight. Of this, 80% is expected to be easily repaired and manufactured to be functional again (prepared for reuse), whereas 20% is anticipated to be in poor condition at the end of its life and is, thus, directed to pure stream recycling, namely to facilities that are capable of separately processing the materials. Non-recyclable insulation materials, classified as hazardous waste, account for 1.5% of the building weight, while services and equipment make up approximately 1% of the building weight and are directly reusable. These end-of-life outcomes provide a score of 64.8 for B.6.3 (corresponding to Good performance).

Table 108. Example of B.6.3 evaluation.

Building element	**Q (expressed as percentage of building weight)**	**c**	**Waste hierarchy**
Wood elements	33	1.00	Direct reuse
	11	0.15	Energy recovery
Reinforced concrete, ceramic and natural stone elements	36	0.50	Mixed stream recycling
Gypsum elements	11	0.50	Mixed stream recycling
Glass and other metal	5.2	0.90	Preparing for reuse
	1.3	0.75	Pure stream recycling
Non-recyclable insulation materials	1.5	0.00	Hazardous waste disposal
Services and equipment	1	1.0	Direct reuse
Indicator score	**64.8**		

Source: JRC.

B.6 KPI score is estimated according to Equation (161) equal to 60, corresponding to a Good performance class and a performance class score of $PCS_{B.6}$ = 70.

4.10 Ensuring high level of aesthetic acceptance of buildings and spaces (B.7)

4.10.1 Description and assessment

The aesthetic acceptance and perception of buildings and spaces are related to the experience of architecture and urban planning by users and/or observers, thus depending on the interaction of users with the built environment through the senses. Aesthetic experience can be understood as the interplay of sensory-motor, emotion-valuation, and knowledge-meaning systems. Due to the dominance of the sense of sight in the relationship between users and the built environment, *Ensuring high level of aesthetic acceptance of buildings and spaces (B.7)* KPI aims to draw attention in architectural and urban design not only to the imperative of satisfying basic functional needs, but also to the unique experiences that activate the different sensory impulses of the audience. A high-quality built environment should be sensory-inclusive and not risk cognitive overload. Indicators of the quality of the aesthetic experience refer to both its attentive, cognitive and affective aspects, as well as to the multisensory perception of buildings and spaces.

Ensuring high level of aesthetic acceptance of buildings and spaces (B.7) KPI is evaluated through the following two indicators to assess the features that allow positive sensory acceptance of buildings and spaces:

— *Visual experience of architecture and space (B.7.1).*

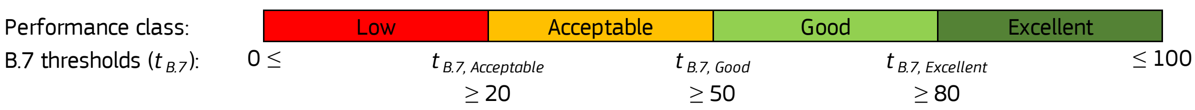
— *Multisensory experience of architecture and space (B.7.2).*

B.7 score, ranging from 0 to 100, is estimated according to Equation (165).

$$B.7 = \sum_{j=1}^{2}\left(w_{B.7.j} \cdot B.1.j\right) \Big/ \sum_{j=1}^{2}\left(w_{B.7.j}\right) = 0.6 \cdot B.7.1 + 0.4 \cdot B.7.2 \qquad (165)$$

Figure 79 provides the B.7 KPI performance classes and thresholds adopted in the self-assessment method. Hence, the four ranges of B.7 score equal to 0 ≤ B.7 < 20, 20 ≤ B.7 < 50, 50 ≤ B.7 < 80, and 80 ≤ B.7 ≤ 100 correspond to *Low*, Acceptable, *Good*, and *Excellent* performance class, respectively. It is highly recommended that B.7 attains as a minimum the Acceptable performance class highlighting the KPI high significance based on expert opinion. This recommendation stems from the lack of standards, guidelines and other certification documents on the aesthetic perception by users of buildings and spaces through the senses. B.7 illustrates the project level of commitment to promoting solutions that foster the multisensory perception of architecture.

Figure 79. B.7 performance classes and thresholds.



Source: JRC.

The B.7 KPI and its corresponding indicators are designed to be implemented at **building**, **neighbourhood** and **urban** scale, including both **newbuild** and **renovation** projects, and both **residential** and **non-residential** use. However, the *visual experience of architecture and space (B.7.1)* indicator is evaluated trough different metrics, developed ad hoc depending on building or neighbourhood/urban scale to which the indicator is applied, as described in detail in Section 4.10.2.

4.10.2 Visual experience of architecture and space (B.7.1)

The *visual experience of architecture and space (B.7.1)* indicator assesses the use of solutions that support and promote a positive visual experience in the aesthetic experience of architecture. B.7.1 indicator, due to its interdisciplinary nature, is assessed through the two following metrics:

- *Visual richness (VisR)*, which refers to the static factors determining the highest level of aesthetic acceptance.
- *Attractiveness of circulation (AC)*, which refers to the dynamic aspects influencing the perception of architecture forms and spaces. Depending on project scale, the attractiveness of circulation metric differs in *attractiveness of circulation at building scale (AC_b)* and *attractiveness of circulation at neighbourhood/urban scale ($AC_{n/u}$)*.

B.7.1 score is evaluated as the weighted average of the scores of the two metrics above, according to Equation (166) or (167), depending on whether the assessment is carried out at building or neighbourhood/urban scale, respectively.

$$B.7.1 = 0.5 \cdot VisR + 0.5 \cdot AC_b \tag{166}$$

$$B.7.1 = 0.5 \cdot VisR + 0.5 \cdot AC_{n/u} \tag{167}$$

Visual richness (VisR) metric for the evaluation of B.7.1 indicator deals with the perception of visual pleasure in relation to buildings, neighbourhood, or urban scale projects, which is inextricably linked to the concept of aesthetic unity, assumed as the most important principle for achieving semantic, visual and functional integrity. The aesthetic unity refers to the coexistence of all parts/elements of a building or a neighbourhood/urban layout that form (irrespective of the chosen style) a harmonious whole.

The *VisR* score is evaluated as the weighted average of four sub-metrics, i.e. *order (O), contrast (C), transparency (Tran),* and *novelty (N)* (Nia and Atun, 2016, Coburn et al., 2017), according to Equation (168).

$$VisR = 0.3 \cdot O + 0.2 \cdot C + 0.3 \cdot T + 0.2 \cdot N \tag{168}$$

Order (O) sub-metric is a design principle in architecture and leads to a structural layout balance and an aesthetic balance in the architectural composition and/or visual hierarchy. All elements of a building, seen by the human eye, are considered, thus including spaces bounded by vertical, horizontal or sloping partitions, the composition (divisions) of these partitions, structural elements, and equipment. Order can be represented by four different layouts, i.e. repetitive, symmetrical, asymmetrical, and curvilinear. Order implies unity of design, thus no randomness is considered in the selection of architectural elements. At neighbourhood and urban scale the order principle is also essential. However, in some cases, e.g. historic cities, other aspects concerning the suitability and respect for the existing surroundings and the *genius loci* may be more important to be considered, thus these assessment aspects need to be prioritised, also to the detriment of the order design principle.

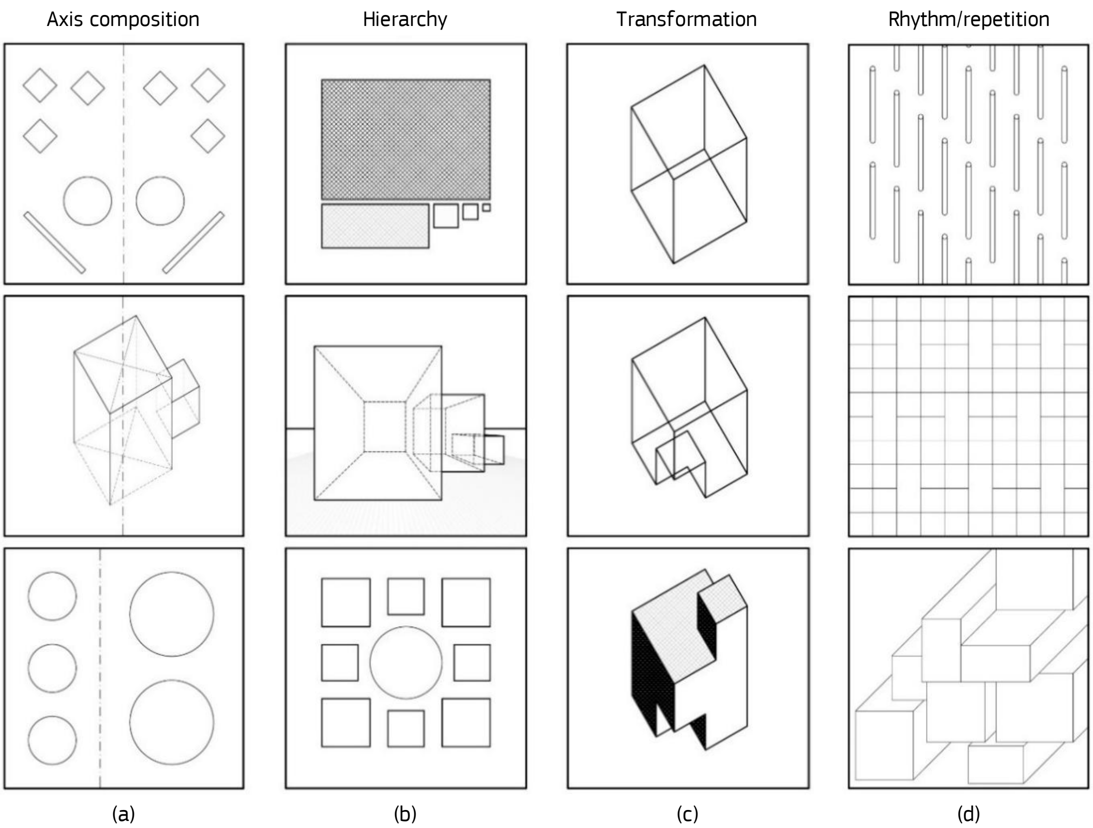
Order sub-metric measures whether a project applies four order principles (Ching, 2015; Hashimoto, 2004), i.e. (*i*) axis composition, (*ii*) hierarchy, (*iii*) transformation, and (*iv*) rhythm/repetition. The presence or absence of each of the four order principles in a project provides four scores, each corresponding to a positive (in the case of presence) or a zero (in the case of absence) value, which are assigned according to the rationale presented in Table 109. The sum of the four scores results into the *order (O)* score, ranging from 0 (i.e. absence of all order principles) to 100 (i.e. presence of all order principles). Definitions of the four order principles are provided in the 'List of abbreviations and definitions' section, and various layout examples for each order principle potentially applied to a project are provided in Figure 80 to facilitate the evaluation of the sub-metric score. The preference for specific types of aesthetic forms is not considered in the score evaluation, as there are no unambiguous criteria useful for determining the major value of an aesthetic form type compared to another. For example, symmetrical or asymmetrical compositions of forms are considered equivalent, so neither of them is preferred. Similarly, the presence of one compositional axis is as valuable as the presence of several compositional axes at the same time. The four order principles can be found in various visually perceived spaces, i.e. on building façades and in street and square frontages, in floor divisions (both in enclosed and open spaces), on walls and ceilings, in the spatial distribution of structural elements of a building (e.g. distribution of columns according to the structural layout of a building, etc.).

Table 109. *Order (O)* sub-metric score.

Order principle	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the four order principles below and sum the corresponding 'yes' scores	
The project applies the following four order principles:	
Axis composition [Figure 80a].	If yes, +25. If no, 0
Hierarchy [Figure 80b].	If yes, +25. If no, 0
Transformation [Figure 80c].	If yes, +25. If no, 0
Rhythm/repetition [Figure 80d].	If yes, +25. If no, 0
Order (O) sub-metric score = Σ ('yes', 'no' scores)	**0 ≤ O ≤ 100**

Source: JRC.

Figure 80. Examples of the four order principles: (a) axis composition, (b) hierarchy, (c) transformation, and (d) rhythm/repetition of columns, grids and masses.



Source: JRC.

Contrast (C) sub-metric is defined as the juxtaposition of opposing elements of an architectural or urban composition (in terms of shapes, materials, colours and textures) in order to emphasise the difference between them and achieve a more dynamic expressiveness. The use of contrasts aims to expose selected architectural elements and create a sense of balance and harmony in the architectural composition of a building, a neighbourhood or an urban layout, so higher levels of contrast can enhance the aesthetic value of a designed building, a neighbourhood or an urban space. Contrast attracts observers' attention, helps to address users' interest in a particular direction, emphasises selected elements and adds variety.

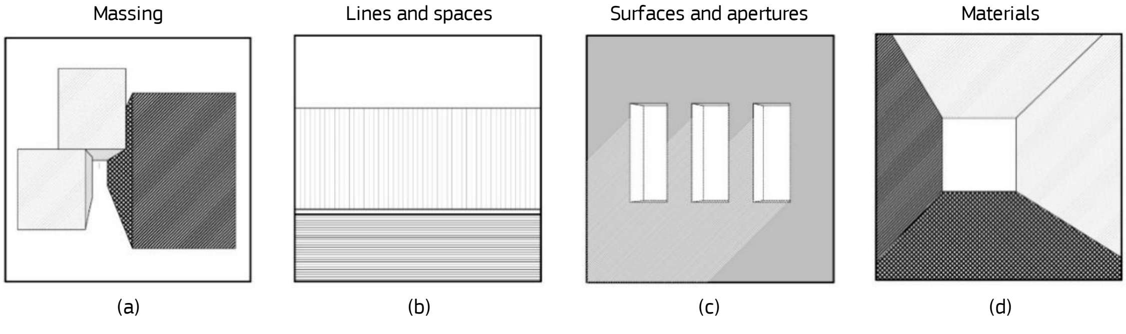
Contrast sub-metric measures whether a project is characterised by the inclusion of contrast concerning four elements, i.e. (*i*) massing (e.g. 'light' and 'heavy' volumes), (*ii*) lines and spaces, (*iii*) surfaces and apertures, (e.g. light and dark surfaces), and (*iv*) materials, assuming the inclusion of contrast as a positive factor enhancing the experience of pleasure in the perception of architecture and space. The presence or absence of each of the four contrasting elements in a project provides four scores, each equal to a positive (in the case of presence) or a zero (in the case of absence) value, which are assigned according to the rationale in Table 110. The sum of the four scores provides the *contrast (C)* sub-metric score, ranging from 0 (i.e. absence of all contrasting elements) to 100 (presence of all contrasting elements). Definitions of massing, aperture, and surface elements are provided in the 'List of abbreviations and definitions' section, and layout examples of the four contrasting elements potentially included into a project are depicted in Figure 81 to facilitate the evaluation of the sub-metric score. It is worth noting that the shapes, colours, and textures of juxtaposed elements are not considered in detail in the evaluation of the contrast sub-metric score, due to the huge variety of spatial architectural solutions.

Table 110. *Contrast (C)* sub-metric score.

Contrasting element	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the four contrasting elements below and sum the corresponding four scores.	
The project is characterised by the contrast of the following four elements, i.e. massing, lines/spaces, surfaces and apertures, and materials:	
1. Contrast of 'light' and 'heavy' massing [Figure 81a].	If yes, + 25. If no, 0
2. Contrast of vertical and horizontal lines/planes, or curved and straight lines/planes [Figure 81b].	If yes, + 25. If no, 0
3. Contrast between surfaces and apertures [Figure 81c].	If yes, + 25. If no, 0
4. Visually contrasting materials, such as light and dark colour materials, transparent and solid materials, smooth and rough texture materials [Figure 81d].	If yes, + 25. If no, 0
Contrast (C) sub-metric score = Σ ('yes', 'no' scores)	**0 ≤ C ≤ 100**

Source: JRC.

Figure 81. Examples of compositions of the four contrasting elements: (a) massing, (b) lines and spaces, (c) surfaces and apertures, and (d) materials.



Source: JRC.

Transparency (Tran) sub-metric relies on the general concept of transparency that describes the characteristics of a material, and the visual clearness of partitions of a building ensuring that enclosed spaces are exposed to light and air. Partitions are understood as building elements with the primary function of separating two usable spaces from each other; partitions can be walls of various kinds, but also screens, furniture, etc.. The transparency of partitions strengthens the relationship between the outside and the inside. In a broader sense, transparency means playing with perception, the interpenetration of successive planes, the deliberate disruption of the sense of depth and distance. Diverse visual effects can be achieved by using materials with different levels of transparency in both building interiors and neighbourhood/urban compositions. Fully translucent glazing offers the possibility of visually combining the interiors of a building or the inside of a building with the outdoor environment. Partitions with less transparency can reduce the inflow and intensity of light, distort the image or produce a variety of optical impressions. A high degree of design sophistication is evidenced by the ability to create a 'play of light and shadow' (i.e. chiaroscuro), intended as the design of visual interactions based on guiding natural light streams (e.g. illuminating a specific point/plane, deliberately providing diffuse light, etc.) and shaping shadow (e.g. as a result of shadow falling on non-transparent planes). The light-shadow effect depending on the time of day and year is particularly valuable. Indeed, the 'control' of the visual effects resulting from the incidence of natural light and the creation of shadow at different times of the day, or year contributes to a suggestive atmosphere of a place and its natural visual variability.

Transparency sub-metric measures whether the aforementioned concepts, translated into four transparency-related aspects concerning (*i*) building interior-exterior visual contact, (*ii*) openings towards landscape, (*iii*) play of light and shadow, and (*iv*) light-shadow effects, are included in a project. The inclusion or lack of each of the four transparency-related aspects in a project results into four scores, each equal to a positive (in the case of inclusion) or a zero (in the case of lack) value, which are assigned according to the rationale provided in Table 111. The sum of the four scores provides the transparency (*Tran*) score, ranging from 0 (i.e. lack of all aspects) to 100 (inclusion of all aspects). Figure 82 provides layout examples of the four transparency-related aspects in architecture, potentially included into a project, to facilitate the evaluation of the sub-metric score.

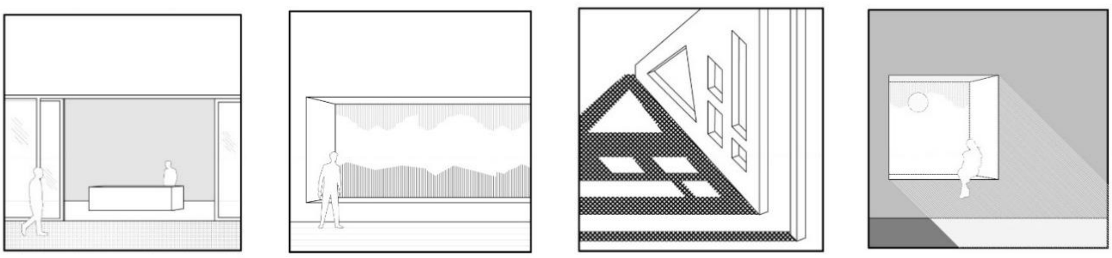
Table 111. *Transparency (Tran)* sub-metric score.

Transparency-related aspects	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the four transparency-related aspects below and sum the corresponding four scores.	
The project is characterised by the following four transparency-related aspects:	
1. Visual contact between the interior and exterior of the building (e.g. particularly desirable transparency of ground floors of buildings located on urban streets [Figure 82a], or – outside the buildings – between separate spaces.	If yes, + 25. If no, 0.
2. Openings towards the landscape, which provide views from a building or neighbourhood/urban layout to natural areas, such as greenery, water reservoirs, fields, meadows, hills, etc. [Figure 82b].	If yes, + 25. If no, 0.
3. Use of 'play of light and shadow', i.e. chiaroscuro, to create the visual richness of the building [Figure 82c].	If yes, + 25. If no, 0.
4. The architectural composition of the building/space considers the following light-shadow effects: (*i*) relationship of light and shadow falling on the interior of the building/space, its partitions or its furnishings, and/or (*ii*) 'chiaroscuro' variation resulting from different times of day/year [Figure 82d].	If yes, + 25. If no, 0.
Transparency (Tran) sub-metric score = Σ ('yes', 'no' scores)	**0 ≤ Tran ≤ 100**

Source: JRC.

Figure 82. Examples of transparency-related aspects in architecture: (a) interior-exterior visual contact, (b) openings, (c) play of light and shadow, and (d) light-shadow effects at different times of day/year.

Interior-exterior visual contact | Openings | Play of light and shadow | Light-shadow effects



(a) (b) (c) (d)

Source: JRC.

Novelty (N) sub-metric focuses on the use of pioneering, over-the-top, unprecedented architectural/spatial solutions in a project resulting into a significative impact on the visual value of the building, neighbourhood or urban scale project. Pioneering solutions in aesthetics can include, for example, the use of structures that result from visionary construction systems, the application of completely new materials (structural, decorative, other) or known materials in unobvious, surprising ways, the incorporation of scientific achievements or the latest socio-cultural trends in the shaping of architectural and urban forms. The novelty sub-metric measures whether a project is characterised by the presence of two novelty-related aspects concerning (*i*) the inclusion of artwork, and (*ii*) the use of aesthetic pioneering solutions, thus resulting into two scores equal to a positive (in the case of presence) or a zero (in the case of absence) value, which are assigned according to the rationale provided in Table 112. The sum of the two scores, providing the novelty sub-metric score, ranges from 0 (i.e. absence of all novelty-related aspects) to 100 (presence of all novelty-related aspects).

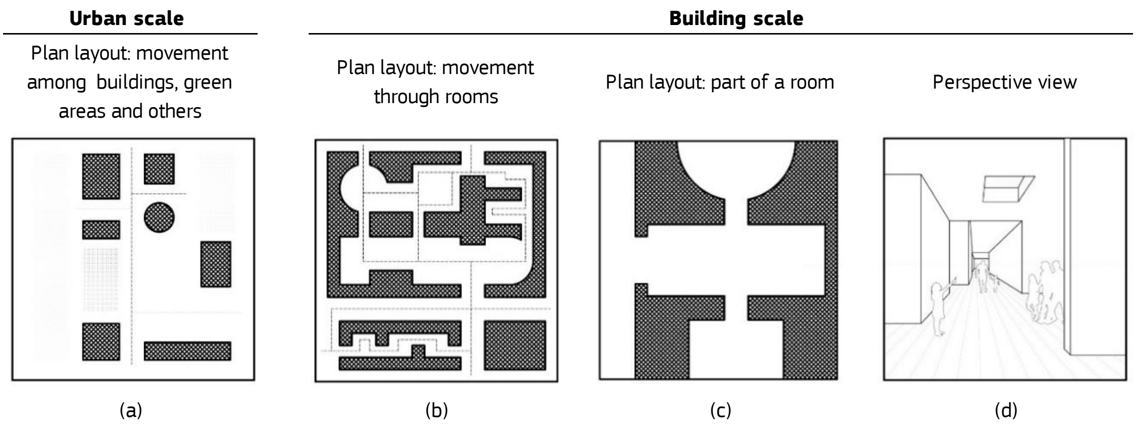
Table 112. *Novelty (N)* sub-metric score.

Novelty-related aspects	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the two novelty-related aspects below and sum the corresponding two scores.	
The project is characterised by the following two novelty-related aspects: 1. The project incorporates meaningfully integrated artwork. 2. The project demonstrates aesthetic pioneering (based on a comparison of the proposed project with existing solutions/realisations).	 If yes, + 50. If no, 0. If yes, + 50. If no, 0.
Novelty (N) sub-metric score = Σ 'yes' , 'no' scores	**0 ≤ N ≤ 100**

Source: JRC.

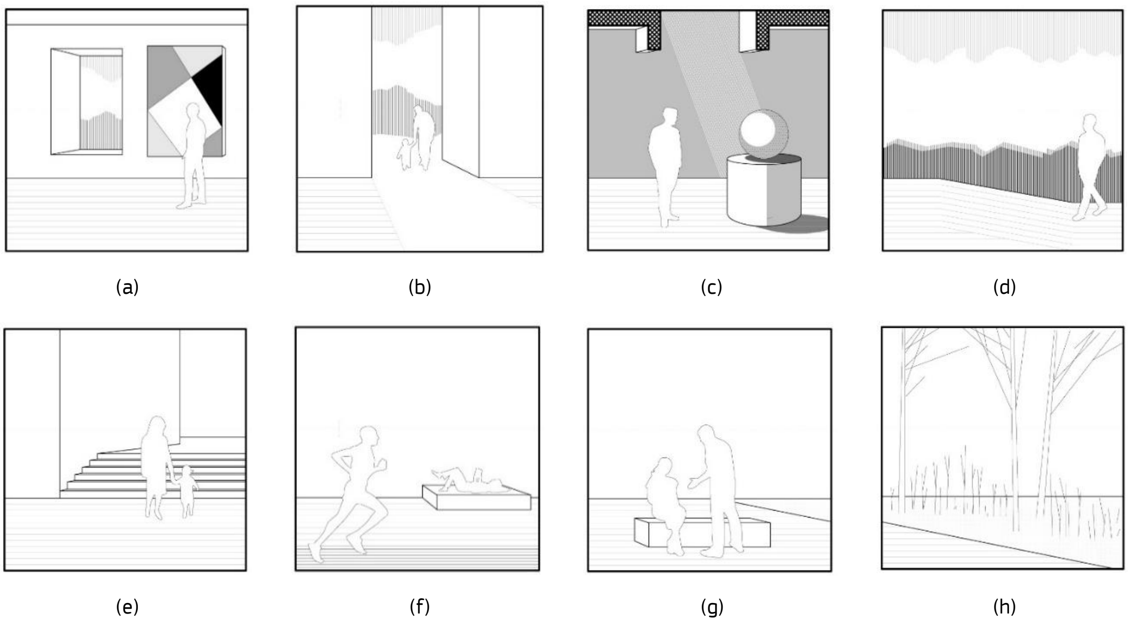
Attractiveness of circulation (AC) metric for the evaluation of B.7.1 indicator refers to the variability of the visual interaction of a user with a building or a neighbourhood/urban composition during his/her movement. Architecture bases its existence on form and space, and their perception depends on the observer's movement, which also influences perception changes. The AC metric allows a three-dimensional (3D) assessment of the visual experience of architecture, beyond the two-dimensional one. The *attractiveness of circulation* metric is based on Le Corbusier's idea of an 'architectural promenade' (Le Corbusier, 1923), which means a sequence of interconnected spaces within a building, neighbourhood, or urban project to be experienced in a specific order, often with the intention of guiding the user/observer through the space and highlighting certain architectural features or views (Samuel, 2010). Circulation refers to the way people move around and interact with a building, a neighbourhood, or an urban project. The user's movement allows viewpoints to be multiplied, the interior of a building to be linked to its immediate surroundings and architecture to be experienced over time. The arrangement of the space must allow for continuous and uninterrupted movement, as depicted in (Figure 83) at both building and neighbourhood/urban scale. Different user experiences can emerge from the movement through an 'architectural promenade' (Figure 84), depending on its design. Indeed, an 'architectural promenade' can be divided into various sections designed to allow a user to move faster or slower, and it can incorporate changes of direction, as well as places for rest and reflection. The ideas of spatial orientation and proximity (i.e. approaching and moving away from a designated position) are also important for the user's movement. The movement path is seen here as a perceptual thread that connects the spaces of a building or any series of indoor and outdoor spaces together.

Figure 83. Potential implementation of an 'architectural promenade' at (a) urban scale, and (b), (c), (d) building scale.



Source: JRC.

Figure 84. Potential user experiences based on the movement through an 'architectural promenade': (a) visual connection with the environment, communing with art, possibility to stop, (b) opening, physical connection with the environment, possibility to change the direction of movement, (c) change of lighting, contrast, play of shadows, change of room height, (d) change of slope of the path, contact with nature, perspective opening, (e) connection with vertical communication (stairs, lifts), change of path height, (f) possibility to change the speed of movement, use of space, (g) possibility to rest, contemplation, (h) direct contact with the natural world.



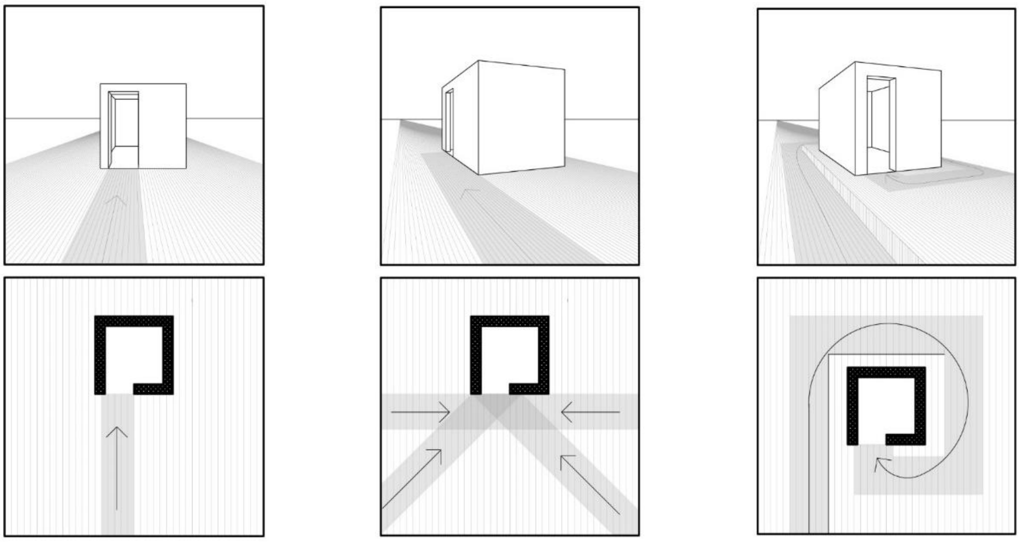
Source: JRC.

The AC metric differs depending on the project spatial scale considered. Specifically the evaluation of the AC metric at building (AC_b) and neighbourhood/urban ($AC_{n/u}$) scales is provided separately in the following.

The ***attractiveness of circulation* at *building* scale (AC_b)** relies on the concept of the 'architectural promenade' focusing on the following five elements (Ching, 2015) for its composition:

— *Approach* deals with a twofold aspect of an 'architectural promenade' composition related to (i) the first view and (ii) the exposition of a building. Indeed, the approach is the first element for the composition of an 'architectural promenade' aimed at preparing the observer to see and experience the interior of a building. The approach can be designed in contrast to the interior space or, conversely, it can be the first space of a sequence, thus blurring the visual differences between the interior and the exterior of a building. The model chosen for the approach (Figure 85) allows for either a partial or multifaceted view of the building and can be used to expose the building in the best possible and most surprising way.

Figure 85. Models of approach to a building



Frontal (direct) approach to the building.

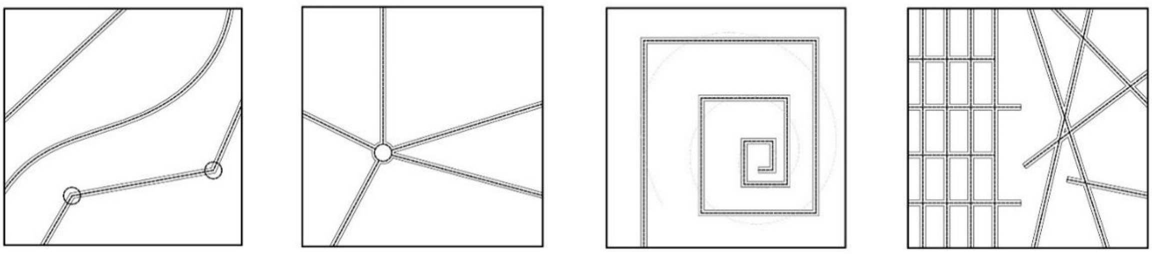
Diagonal approach to the building

Spiral approach to the building

Source: JRC.

- *Entrance* (from outside to inside) refers not only to the physical passage between the exterior and the interior of a building, but also to the interior space associated with the entrance, which is an invitation to explore the building and a node for the distribution of movement.
- *Configuration of the path* refers to the arrangement of connections within a sequence of spaces. All paths for the movement of people and vehicles have a linear configuration, characterised by a starting and an ending point, as well as intersections with other paths and spaces (Figure 86). The form and scale of entrances and paths should emphasise the functional and symbolic distinction between spaces. The nature of the pathway configuration both influences and is influenced by the organisational pattern of the connecting spaces. Path does not literally mean a lane, alley or footpath. It is a possible way for people to move through space (Figure 87), including open spaces, such as squares. The path does not have to be flat; necessarily; it can change the height levels, rise or descend, and vertically connect different planes by means of stairs, ramps, and lifts (Figure 88).

Figure 86. Configuration of paths for people movement



Linear path (straight, curved, segmented) configuration

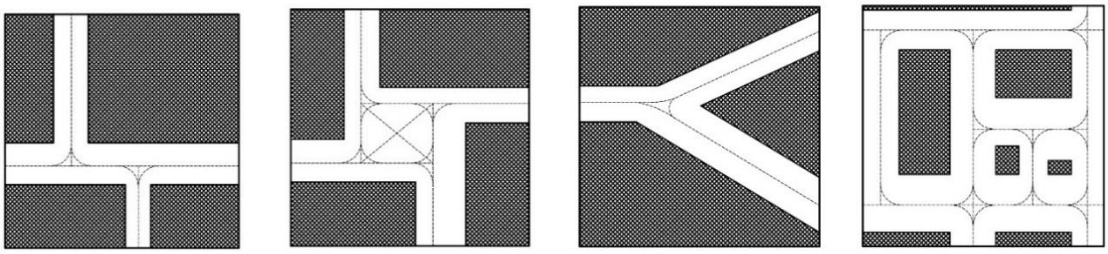
Radial path configuration

Spiral path configuration

Grid (left) and **network** (right) path configuration

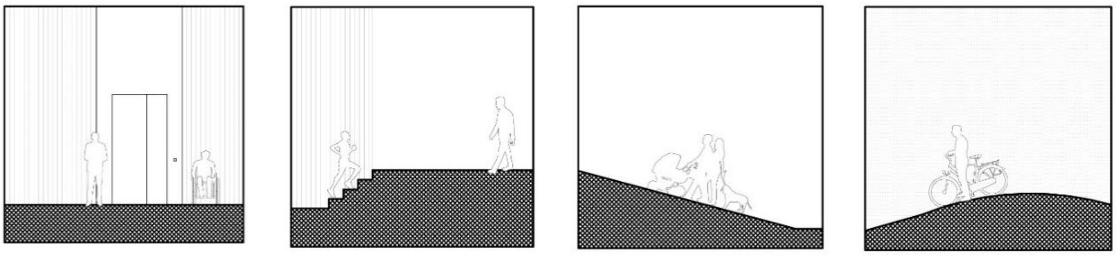
Source: JRC.

Figure 87. Spatial solutions to support the decision-making of space users regarding the choice of movement direction (the number of path intersections enhances the decision-making process).



Source: JRC.

Figure 88. Path alignment: (a) flat, (b) multi-level with direct vertical connection using stairs, (c) ramps or (d) sloping terrain.

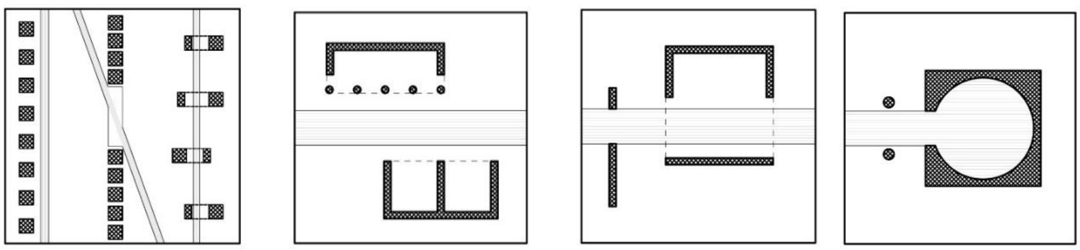


(a) (b) (c) (d)

Source: JRC.

— *Path-space relationships* identify ways in which paths are linked to spaces (interiors in buildings/urban interiors), leading the position of a path to have a direct impact on the users' perception. Paths can be tangential to sequences of spaces, so that the spaces remain distinct. Paths can be routed through spaces axially, diagonally or along their edges, opening up many possibilities for arrangement (Figure 89).

Figure 89. Path-space relationship.



Paths running (from left): **axial**, **diagonal** and **through spaces**

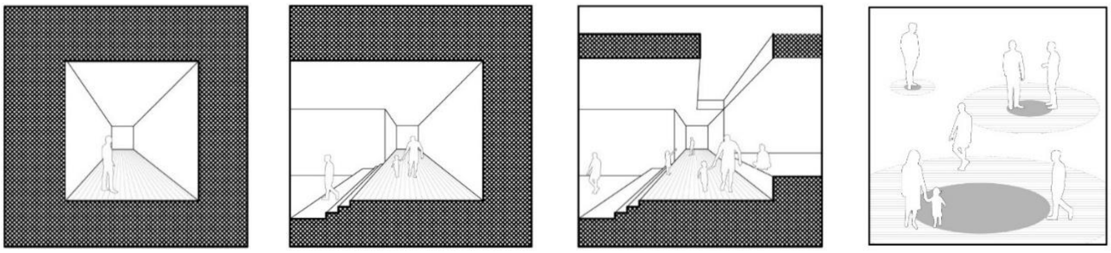
Path **passing by** spaces (buildings, etc.)

Path **passing through** spaces (buildings, etc.)

Source: JRC.

— *Form of the circulation space*, which is an integral part of the layout of any building, along with its scale should take into account the volume of traffic, the number of users, the stopping places, the resting places, and the proxemics (Figure 90).

Figure 90. Form of the circulation space and proxemics.



Closed form of circulation space | Circulation space **open** on **one side** | Circulation space **open** on **both side** | **Proxemics** in the building/space – Distances: personal, social, and public

Source: JRC.

Attractiveness of circulation at building scale (AC_b) evaluates the extent to which design solutions related to the five elements of the composition of the 'architectural promenade' that positively influence the perception of the forms and spaces of the building are included in a building project. The rationale for the evaluation of AC_b score is summarised in Table 113. AC_b score can be equal to four different fixed values (i.e. 0, 40, 70, 100) indicative of four performance classes (i.e. low, acceptable, good, and excellent) of the attractiveness of circulation attained, noting though that metric performance classes are not used in the current version of the self-assessment method.

Table 113. *Attractiveness of circulation at building scale (AC_b)* sub-metric score.

Sub-metric	**Score**
Select single value below.	
The project includes the following design solutions related to the '*form of the circulation space*' element: — **Form of the circulation space** The form and scale of circulation spaces take into account the movement of people, and the opportunity to stop and rest.	0 (Low)
The project includes the following design solutions related to the '*form of the circulation space*' element: — **Form of the circulation space** Differentiated proxemics are included in the building by considering the following distances: public (3.7 m to 7.6 m and more), social (1.2 m to 3.7 m) and personal (0.45 m to 1.2 m) (Hall, 1990) [Figure 90].	*Check the next three groups of design solutions below (select single value)*
The project includes ***at least three*** of the following design solutions related to the five elements of the architectural promenade: — **Approach** Frontal, direct approach, i.e. a straight, axial path terminating in an entrance to the building or a defined space within the building [Figure 85]. — **Entrance** The boundary between the exterior and interior of the building is clear, the location of the entrance is marked by a defined spatial form. — **Configuration of the path** A simple linear layout as an organising/connecting element of a series of spaces (e.g. rooms in a building) [Figure 86]. In the case of multi-level promenades, the levels are vertically connected (e.g. stairs, ramps, lifts) [Figure 88]. — **Path-space relationship** The path is independent and does not cross the space (e.g. it is located tangentially to rooms, spaces) [Figure 89]. — **Form of the circulation space** The path has a closed form and connects to the spaces through entrances in the wall planes [Figure 90].	40 (Acceptable)
The project includes ***at least half*** of all following design solutions related to the five elements of the architectural promenade and further features enhancing the user experience: — **Approach** A diagonal approach that enhances the effect of perspective and allows a wider view of the front of the building and its entrance area [Figure 85]. — **Entrance** The entrance zone encourages exploration of the interior by providing transparency of the partitions/structural arrangement and legibility of the possible directions for further journey.	70 (Good)

— **Configuration of the path** Advanced layouts of segmented lines, either radial or spiral layouts as organising/connecting elements of a sequence of spaces [Figure 86]. Supporting the choice of movement paths [Figure 87]. In the case of multi-level promenades, the levels are vertically connected by semi-open stairs and ramps [Figure 88]. — **Path-space relationship** The path cuts through the spaces, allowing direct views of the interiors [Figure 89]. — **Form of the circulation space** The pathway has a one-side open form to provide visual and spatial continuity with the spaces it connects [Figure 90]. — **Further features enhancing user experience** The length of users' direct exposure to nature is between 25-50 % of the length of the entire promenade.	
The project includes ***at least half*** of all following design solutions related to the five elements of the architectural promenade and further features enhancing the user experience: — **Approach** A spiral approach to the building, guided in a way that emphasises its three-dimensionality [Figure 85]. — **Entrance** The entrance to the building is a real or implied plane perpendicular to the path of approach, and the entrance area encourages exploration of the interior by providing clarity of partitions/structural layout and legibility of possible directions of further travel. — **Configuration of the path** Advanced network layouts with hierarchical structured paths [Figure 86]. Nodal spaces that provide opportunities to stop, rest, change direction of movement [Figure 87]. In the case of multi-level promenades, the levels are vertically connected by stairs and ramps, resolved as open interior elements [Figure 88]. — **Path-space relationship** The location/layout of the spaces determines the path modelling, and their relationship has been planned in such a way as to emphasise the functional or symbolic meaning of the particular interiors/spaces. — **Form of the circulation space** The path has an open form [Figure 90]. — **Further features enhancing user experience** The length of direct exposure of users to nature exceeds 50 % of the length of the entire promenade. The design of the promenade includes the concept of integrating architecture and art at least in the entrance spaces/zones (WELL v2, IWBI, 2020).	100 (Excellent)
AC_b metric score = Selected sub-metric score	**AC_b = 0 or 40 or 70 or 100**

Source: JRC.

The ***attractiveness of circulation*** at ***neighbourhood and urban* scale ($AC_{n/u}$)** metric relies on four elements (i.e. paths, edges, nodes, and landmarks) of the city imageability theory (Lynch, 1964), which are perceived by the observers to shape their view of the built environment, thus 'experiencing the city'. The metric is also based on the concept of the 'architectural promenade' and biophilic design paradigms.

$Ac_{n/u}$ score is evaluated as the weighted average of four sub-metrics, i.e. paths (P), edges (E), nodes, and landmarks (L) (Lynch, 1964), according to Equation (169):

$$AC_{n/u} = 0.25 \cdot P + 0.25 \cdot E + 0.25 \cdot Nodes + 0.25 \cdot \mathrm{L} \qquad (169)$$

Paths (*P)* refer to 'corridors' of movement identified bystreets, pavements, pedestrian areas, tram and rail lines, waterways, etc. at urban scale to provide continuous 'traffic channels' and a safe connection between spaces with different functions. Paths designed for pedestrians need to be friendly to users with different mobility abilities. Further explanations concerning the concept of path can be also found in the description of *configuration of the path* and *path-space relationship* elements of the architectural promenade composition in the AC_b metric.

Paths sub-metric measures whether a project at neighbourhood or urban scale satisfies seven specific design characteristics related to the paths (as indicated in Table 114). The presence or absence of each of these seven characteristics provides seven partial scores, each equal to a positive (in the case of presence) or a negative (in the case of absence) values, which are assigned according to the rationale summarised in Table 114. The sum of the seven scores estimates the paths (P) sub-metric score, ranging from 0 (absence of all design characteristics) to 100 (presence of all design characteristics).

Table 114. *Paths (P)* sub-metric score.

Path design characteristic	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the seven design characteristics below and sum the corresponding seven scores.	
The project includes the following design solutions related to the paths:	
1. A composition that uses the existing topography.	If yes, + 20. If no, 0.
2. A composition that uses the existing development with particular attention to existing greenery.	If yes, + 20. If no, 0.
3. Compositional elements that give a sense of variation due to the mutual positioning of elements, different textures, colours, sizes, shapes, and spatial arrangement.	If yes, + 12. If no, 0.
4. Multi-level pathways with the different levels linked by accessible ramps to experience a variety of visual impressions, allowing perspectives, insights and views to open up.	If yes, + 12. If no, 0.
5. Variations in movement directions.	If yes, + 12. If no, 0.
6. New greenery/water elements that are integral part of the project (e.g. linear tree systems, water pools, individual plants of special importance).	If yes, + 12. If no, 0.
7. Use of urban furniture.	If yes, + 12. If no, 0.
Paths (P) sub-metric score = Σ ('yes', 'no' scores)	**0 ≤ P ≤ 100**

Source: JRC.

Edges (E) are both physical and symbolic boundaries. At neighbourhood or urban scale, edges can be continuous building lines, riverbeds, as well as lines that define transitions between different spaces. An edge can also refer to the interface between a building and its neighbourhood. A boundary can be a spatial barrier, making it difficult or even impossible to cross, or it can be merely a spatial 'signal' informing for a change of land use, material, aesthetics. It is important to consider this potential restriction of access or view in the design, thus avoiding randomness. The boundary with the strongest impact on users is characterised by continuity and logic. The continuity of a boundary can be achieved, by clear compositional lines in vertical spaces (i.e. walls, ramparts, etc.) or horizontal spaces (i.e. floors, building boundaries, river lines, paths), repeated spatial or point arrangements (including greenery). At the architectural scale, an edge can be a material partition, but also a line deliberately hidden to create a sense of continuity between the interior and exterior of a building.

Edges sub-metric assesses whether a project at neighbourhood or urban scale satisfies three specific design characteristics for the edges (as indicated in Table 115). The presence or absence of each of these three characteristics provides three corresponding partial scores, each equal to a positive (in the case of presence) or a negative (in the case of absence) value, which are assigned according to the rationale summarised in Table 114. The sum of the three scores estimates the edges (E) sub-metric score, ranging from 0 (absence of all design characteristics) to 100 (presence of all design characteristics).

Table 115. *Edges (E)* sub-metric score.

Edges design characteristics	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the three design characteristics below and sum the corresponding three scores.	
The project includes the following design characteristics related to the edges:	
1. The boundary between spaces is clear to the viewer and it is expressed in a physical way, visible in the spatial design (i.e. materials used, composition, scale, greenery, water, etc.) or in a symbolic way (i.e. symbolic identification, play of sun and shadows, etc.).	If yes, + 35. If no, 0.
2. An edge, through visual or spatial treatments such as distinction by form, material, composition, is a clear signal of change (e.g. change of use, change of aesthetics, change of accessibility, physical or symbolic transition).	If yes, + 35. If no, 0.
3. The edge is characterised by compositional continuity.	If yes, + 30. If no, 0.
Edges (E) sub-metric score = Σ ('yes', 'no' scores)	**0 ≤ E ≤ 100**

Source: JRC.

Nodes are defined as central places in urban layouts, where lines of communication can converge, but they can also be multifunctional spaces, pedestrian-friendly and suitable for use by large groups of people. Nodes are accessible, they are points of connection and interaction, places of contact. They can be closed (when they are limited by clear boundaries, visual or physical barriers), open (when they open up to their surroundings, such as natural landscapes) or semi-open, understood as a combination of the characteristics of the two previous types.

Nodes sub-metric assesses whether a project at neighbourhood or urban scale includes four specific design characteristics for the nodes (as indicated in Table 116). The presence or absence of each of these four characteristics provides four corresponding partial scores, each equal to a positive (in the case of presence) or a negative (in the case of absence) value, which is assigned according to the rationale summarised in Table

116. The sum of the four scores estimates the nodes sub-metric score, ranging from 0 (lack of all design characteristics) to 100 (inclusion of all design characteristics).

Table 116. *Nodes* sub-metric score.

Nodes design characteristics	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the four design characteristics below and sum the corresponding four scores	
The project provides the following design solutions related to the nodes:	
1. In the node, conceived as a public space, pedestrians are allowed freedom of movement and choice of observation directions, offering a varied visual experience.	If yes, + 25. If no, 0.
2. The node is accessed by paths (e.g. roads, streets, pedestrian paths, others) with a clear direction and hierarchical rank (manifested e.g. by differentiation in terms of size, quality of finishing materials, urban furniture, aesthetics).	If yes, + 25. If no, 0.
3. Arrangement of green or water areas in the spatial structure of the node.	If yes, + 25. If no, 0.
4. Integration of the node with its surroundings, in the case of open structures offering a visual connection with natural or urban landscapes.	If yes, + 25. If no, 0.
Nodes sub-metric score = Σ ('yes', 'no' scores)	**0 ≤ Nodes ≤ 100**

Source: JRC.

Landmarks (L) are points of orientation, signs and symbols that are distinctive and easily recognisable. Landmarks tend to be focal points for observers and are also elements of urban identity.

Landmarks sub-metric assesses whether a project at neighbourhood or urban scale satisfies five specific design characteristics for the landmarks (as indicated in Table 117). The presence or absence of each of these five design characteristics provides five partial scores, each equal to a positive (in the case of presence) or a negative (in the case of absence) value, which is assigned according to the rationale summarised in Table 117. The sum of the five scores estimates the landmarks (L) sub-metric score, ranging from 0 (absence of all design characteristics) to 100 (presence of all design characteristics).

Table 117. *Landmarks (L)* sub-metric score.

Landmarks design characteristics	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the five design characteristics below and sum the corresponding five scores	
The project includes the following design characteristics related to landmarks:	
5. Location in places of particular importance for the composition of the whole layout.	If yes, + 20. If no, 0.
6. Exposure allowing the view in motion and from different positions.	If yes, + 20. If no, 0.
7. Influence on the silhouette of the urban layout.	If yes, + 20. If no, 0.
8. Distinctive forms focusing the observers' attention.	If yes, + 20. If no, 0.
9. Legibility of the forms allowing them to be easily identified (and remembered) as a site-specific cultural/natural element.	If yes, + 20. If no, 0.
Landmarks (L) sub-metric score = Σ ('yes', 'no' scores)	**0 ≤ L ≤ 100**

Source: JRC.

4.10.3 Multisensory experience of architecture and space (B.7.2)

The *multisensory experience of architecture and space (B.7.2)* indicator refers to the sensory, but non-visual, impact of the built environment, which can stimulate users on a social, cognitive and emotional level (Spence, 2020). B.7.2 is assessed through the following three metrics:

— *Tactile richness (TR).*

— *Auditory richness (AR).*

— *Olfactory richness (OR).*

B.7.2 score is evaluated as the weighted average of the scores of the three metrics above, according to Equation (170), in which the values assumed for the metric weights depend on the human brain sensitivity to the information conveyed through each specific human sense (Spence, 2020).

$$B.7.2 = 0.5 \cdot TR + 0.3 \cdot AR + 0.2 \cdot OR \quad (170)$$

The *tactile richness (TR)* metric for the evaluation of the B.7.2 indicator concerns tactile experiences, which increase the engagement and satisfaction of users of buildings and urban open spaces. The improvement of these experiences can be achieved by using: differentiated materials and textures on all building surfaces with a particular focus on floors, as well as interior furnishings providing a sense of comfort. Since tactile receptors are located all over the human body, tactile sensory experience can be realised through a set of activities, ranging from walking (i.e. contact with the floor), sitting/lying, touching surfaces and furnishings. The tactile sensory experience is enhanced by the use of textures with a variety of physical characteristics, such as smooth-rough, bumpy-flat, hard-soft, slippery-sticky, wet-dry, or by juxtaposing elements with different temperatures, e.g. warm-cold water.

The metric evaluates the extent to which the use of specific design solutions (as indicated in Table 118) allows a building, a neighbourhood or an urban scale project to be pleasantly experienced by users through their tactile sense. The rationale for the evaluation of the TR score is summarised in Table 118. TR score can be equal to four different fixed values (i.e. 0 40, 70, 100) indicative of four performance classes (i.e. low, acceptable, good, and excellent) of the tactile richness attained, noting though that metric performance classes are not used in the current version of the self-assessment method.

Table 118. *Tactile richness (TR)* metric score.

Sub-metric	**Score**
Select single value below.	
The project provides a neutral tactile experience (i.e. no factor influences the tactile experience negatively) in terms of choice of finishing materials, i.e. floor and wall coverings, and furnishings.	0 (Low)
The project attains the low tactile richness and provides a pleasant tactile experience through the use of the following design solution: — Choice of finishing materials, i.e. floor and wall coverings and other furnishings, specifically designed to enhance the tactile experience.	40 (Acceptable)
The project includes the design solutions to attain the acceptable tactile richness and provides an advanced tactile experience through the use of the following additional design solutions: — Intentional juxtaposition of flat surfaces (i.e. user-accessible floors, walls and partitions) with varying and contrasting textures (i.e. smooth-rough, bumpy-flat, hard-soft, warm-cold, slippery-sticky). — Contact with natural finishes and decorative materials, greenery, and/or water provided to the users.	70 (Good)
The project includes the design solutions to attain the good tactile richness and provides a more advanced tactile experience through the use of the following additional design solutions: — Tactile elements being part of the spatial identification system, such as spatial models, clear texture changes with additional information (e.g. definition of boundaries indicating change of use of the space and access control). — Spaces/elements stimulating tactile perception and encouraging physical contact, such as the provision of adaptive elements that can be changed by the users (e.g. mobile/foldable spatial installations, 'Do It Yourself' objects for self-assembly), digital multi-touch and gesture interactive elements. — Solutions taking into account the needs of different users (i.e. children, people with special needs), such as sensory spaces.	100 (Excellent)
TR metric score = Selected sub-metric score	**TR = 0 or 40 or 70 or 100**

Source: JRC.

The *auditory richness (AR)* metric for the evaluation of the B.7.2 indicator concerns the user experience related to the sound in buildings, neighbourhoods, and urban scale projects. The acoustic experience in buildings, neighbourhoods, and urban spaces tend to focus on ways of avoiding or minimising noise, i.e. 'unwanted sound'. However, sound can create an identity for a place, provide clues about the proportions of a space, and also suggest its functions. The sounds of nature are beneficial to the well-being of users of buildings and urban spaces and can also serve to mask the noise of the city (Gelfand, 2017).

The metric evaluates the extent to which the use of specific design solutions (as indicated in Table 119) allows a building, a neighbourhood or an urban scale project to be positively experienced by users through their auditory sense. The evaluation of the AR score is summarised in Table 119. AR score can be equal to four different fixed values indicative of four performance levels (i.e. low, acceptable, good, and excellent) of the auditory richness attained, noting though that metric performance classes are not used in the current version of the self-assessment method.

Table 119. Auditory richness (AR) metric score.

Sub-metric	Score
Select single value below.	
The project provides a neutral sound experience (i.e. no factor influences the auditory perception negatively).	0 (Low)
The project exceeds the low auditory richness by providing an acoustic experience through the following design solutions: — Creation of spaces with varying sound intensity. — Use of partitions and materials that muffle, absorb or diffuse sound.	40 (Acceptable)
The project includes the design solutions to attain the acceptable auditory richness, and provides an advanced acoustic experience through the following additional design solutions: — Intentional exposure of users to natural sounds. — Use of devices that allow users to adjust sound levels.	70 (Good)
The project includes the design solutions to attain the good auditory richness, and provides a more advanced acoustic experience through ***at least two*** of the following additional design solutions: — Sound stimulation spaces, quiet rooms, or sound experience rooms. — Arrangement of spaces where sound carries additional cognitive information (e.g. regarding the function of rooms/spaces). — Innovative solutions in terms of sound experience (e.g. use of personalised sound technology, implementation of innovations in 3D sound systems).	100 (Excellent
AR metric score = **Selected sub-metric score**	**AR = 0 or 40 or 70 or 100**

Source: JRC.

The *olfactory richness (OR)* metric for the evaluation of B.7.2 indicator concerns the olfactory experience in buildings, neighbourhoods and urban scale projects. Smell is considered one of the means for memory creation, so the purposeful use of the olfactory sense can enrich the experience of building users. The inclusion of smell in architectural design is part of the development of solutions taking into account the relationship between all the sensory channels used to read and perceive the surrounding space. The olfactory sense is continuously active, so the absence or elimination of factors affecting this sense negatively should be considered as a starting point for an effective project, while the design of spaces that positively stimulate the sense of smell should be promoted.

The metric evaluates the extent to which the inclusion of specific design solutions (as indicated in Table 120) allows a building, a neighbourhood, or an urban scale project to be positively experienced by users through their olfactory sense. The evaluation of the OR score is summarised in Table 120. OR score can be equal to four different fixed values indicative of four performance levels (i.e. low, acceptable, good, and excellent) of the olfactory richness attained, noting though that metric performance classes are not used in the current version of the self-assessment method.

Table 120. *Olfactory richness (OR)* metric score.

Sub-metric	Score
Select single value below.	
The project provides a neutral olfactory experience (i.e. no factor influences the perception of building/ neighbourhood/urban project negatively).	0 (Low)
The project exceeds the low olfactory richness by providing an olfactory experience through the following additional design solutions: — The intentional use of varied finishing materials with naturally pleasant fragrances (e.g. different types of natural wood).	40 (Acceptable)
The project includes the design solutions to attain the acceptable olfactory richness and provides an advanced olfactory experience through the following additional design solutions: — Intentional use of natural fragrant elements in the design, such as earth, water, greenery and flowers.	70 (Good)
The project includes the design solutions to attain the good olfactory richness and provides *at least two* of the following additional design solutions: — Olfactory stimulation spaces (e.g. scent gardens) in building interiors. — Specific fragrance compositions creating particularly pleasant olfactory experience changing in time (e.g. different flowers or herbs emitting aroma early morning, during the day and at the sunset/after dark) and space (e.g. user can sense different aromas when passing from one floral composition to another). — Innovative solutions in terms of the olfactory experience, unprecedented in architectural and urban design (e.g. the use of digital, personalised olfactory systems).	100 (Excellent)
OR metric score = **Selected sub-metric score**	**OR = 0 or 40 or 70 or 100**

Source: JRC.

4.10.4 Example (B.7)

A free-standing public building, newly constructed in a historic environment, is considered. The four-storey building houses a contemporary art museum, shops, restaurants and artist studios. The scale of the building was adapted to the neighbouring buildings. The building is designed as a quadrangle with an inner courtyard, which is open to the general public (not exclusively to the direct users of the building). The courtyard forms part of the public space and the ground floor of the building is largely open (the structural elements of the building are visible). The courtyard features a green area and a water reservoir (e.g. fountain, small pool, etc.), as well as an open-air amphitheatre and an outdoor art exhibition. The building exhibits several features of the contemporary modernism style, with its façades heavily glazed, rectangular forms, monochromatic colours specific for the building materials used. Additionally, a number of pro-ecological solutions can be observed, including exposure to natural light (diffused due to the building function), greenery in the interiors, natural materials in the interior arrangement, vertical green systems (VGS) and water body for evaporative cooling.

The evaluation of B.7 depends on the scores of *visual experience of architecture and space (B.7.1)* and *multisensory experience of architecture and space (B.7.2)* indicators, thus their estimation is first carried out.

The **B.7.1 score** is evaluated through the following two metrics: (*i*) visual richness (VisR) and (*ii*) attractiveness of circulation at building scale (AC_b).

Visual richness (VisR) metric is evaluated according to the four sub-metrics in Table 109, Table 110, Table 111, and Table 112. Specifically, order, contrast, transparency, and novelty sub-metric scores are based on the presence in the example building of two (out of four) order principles, three (out of four) contrasting elements, three (out of four) transparency-relayed aspects, and one (out of two) novelty-related aspects, respectively, as reported in Table 121. Having evaluated the score for each sub-metric, the visual richness score is estimated according to Equation (168), as reported in Table 121.

Table 121. Example of visual richness (VisR) metric evaluation.

Order principle	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the four order principles below and sum the corresponding 'yes' scores.	
The project applies the following four order principles: 1. Axis composition. 2. Hierarchy 3. Transformation 4. Rhythm/repetition	 Yes, +25. No, 0. No, 0. Yes, +25.
Order (O) sub-metric score = Σ ('yes', 'no' scores)	**O = 50**
Contrasting element	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the four contrasting elements below and sum the corresponding four scores,	
The project is characterised by the contrast of the following four elements, i.e. massing, lines/spaces, surfaces and apertures, and materials: 1. Contrast of 'light' and 'heavy' massing. 2. Contrast of vertical and horizontal lines/planes, or curved and straight lines/planes. 3. Contrast between surfaces and apertures. 4. Visually contrasting materials, i.e. transparent and solid materials.	 No, 0. Yes, + 25. Yes, + 25. Yes, + 25.
Contrast (C) sub-metric score = Σ ('yes', 'no' scores)	**C = 75**
Transparency-related aspects	**Score**
Indicate the inclusion, i.e. yes, or lack, i.e. no, of each of the four transparency-related aspects below and sum the corresponding four scores,	
The project is characterised by the following four transparency-related aspects: 1. Visual contact between the interior and exterior of the building. 2. Openings towards the landscape, which provide views from a building or urban layout to natural areas. 3. Use of 'play of light and shadow', i.e. chiaroscuro, to create the visual richness of the building. 4. The architectural composition of the building/space considers the following light-shadow effects: (*i*) relationship of light and shadow falling on the interior of the building/space, its partitions or its furnishings, and/or. (*ii*) 'chiaroscuro' variation resulting from different times of day/year.	 Yes, + 25. No, 0. Yes, + 25. No, 0.
Transparency (T) sub-metric score = Σ ('yes', 'no' scores)	**T = 50**
Novelty-related aspects	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the two novelty-related aspects below and sum the corresponding four scores,	

The following two novelty-related aspects are considered in the project: 1. The project incorporates meaningfully integrated artwork. 2. The project demonstrates aesthetic pioneering (based on a comparison of the proposed project with existing solutions/realisations).	Yes, + 50. No, 0.
Novelty (N) sub-metric score = Σ 'yes', 'no' scores	**N = 50**
Visual richness (VisR) metric score = 0.3 · 50 + 0.2 · 75 + 0.3 · 50 + 0.2 · 50	**VisR = 55**

Source: JRC.

Attractiveness of circulation at building scale (AC_b) metric is evaluated by comparing the design solutions of the example building to the design characteristics related to the five elements of the architectural promenade composition, according to the sub-metrics in Table 113. Based on the comparison results, the example building includes the design solutions indicated in Table 122, thus the score of attractiveness of circulation at building scale is rated equal to 100.

Table 122. Example of attractiveness of circulation at building scale (AC_b) metric evaluation.

Sub-metric	Score
The project includes the following design solutions related to the '*form of the circulation space*' element: **Form of the circulation space** Differentiated proxemics are included in the building by considering the following distances: public (3.7 m to 7.6 m and more), social (1.2 m to 3.7 m) and personal (0.45 m to 1.2 m) (Hall, 1990):	
The project includes the following design solutions related both to the five elements of the architectural promenade and to further features enhancing the user experience: — **Approach** A spiral approach to the building, guided in a way that emphasises its three-dimensionality. — **Configuration of the path** Nodal spaces that provide opportunities to stop, rest, change direction of movement. — **Path-space relationship** The location/layout of the spaces determines the path modelling, and their relationship has been planned in such a way as to emphasise the functional or symbolic meaning of the particular interiors. — **Form of the circulation space** The paths have an open form. — **Further features enhancing user experience** The length of direct exposure of users to nature exceeds 50 % of the length of the entire promenade. The design of the promenade includes the concept of integrating architecture and art at least in the entrance spaces/zones.	100 (Excellent)
AC_b metric score = Selected sub-metric score	**AC_b = 100**

Source: JRC.

Having evaluated the score for each metric, B.7.1 is estimated according to Equation (166), as reported in Table 123.

Table 123. Example of B.7.1 evaluation.

Metric	**VisR**	**AC_b**
Metric score	55	100
B.7.1 score	= 0.5 · 55 + 0.5 · 100 = 77.5	

Source: JRC.

The **B.7.2 score** is evaluated through the following three metrics: (*i*) tactile richness, (*ii*) auditory richness, and (*iii*) olfactory richness. Specifically, the three metrics are evaluated by comparing the design solutions of the example building with the ones indicated as reference to allow users to positively experience a project through their tactile, acoustic, and olfactory senses, according to the sub-metrics in Table 118, Table 119, and Table 120, respectively. Based on the comparison results, the example building includes the use of the design solutions reported in Table 124, thus leading to the tactile richness, auditory richness, and olfactory richness scores equal to 70, 40, and 70, respectively.

Table 124. Example of tactile richness (TR), auditory richness (AR), and olfactory richness (OR) metrics evaluation

Tactile richness (TR)	
Sub-metric	**Score**
The project includes the design solutions to attain the acceptable tactile richness and provides an advanced tactile experience through the use of the following additional design solutions: — Intentional juxtaposition of flat surfaces (i.e. user-accessible floors, walls and partitions) with varying and contrasting textures (i.e. smooth-rough, bumpy-flat, hard-soft, warm-cold, slippery-sticky). — Contact with natural finishes and decorative materials, greenery, and/or water provided to the users.	70 (Good)
TR metric score = Selected sub-metric score	**TR = 70**
Auditory richness (AR)	
Sub-metric	**Score**
The project exceeds the low auditory richness by providing an acoustic experience through the following design solutions: — Creation of spaces with varying sound intensity. — Use of partitions and materials that muffle, absorb or diffuse sound.	40 (Acceptable)
AR metric score = **Selected sub-metric score**	**AR = 40**
Olfactory richness (OR)	
Sub-metric	**Score**
The project includes the design solutions to attain the acceptable olfactory richness and provides an advanced olfactory experience through the following additional design solutions: — Intentional use of natural fragrant elements in the design, such as earth, water, greenery and flowers.	70 (Good)
OR metric score = **Selected sub-metric score**	**OR = 70**

Source: JRC.

Having evaluated the score for each metric, B.7.2 is estimated using Equation (170), as reported in Table 125.

Table 125. Example of B.7.2 evaluation.

Metric	**TR**	**AR**	**OR**
Metric score	70	40	70
B.7.2 score	= 0.5 · 70 + 0.3 · 40 + 0.2 · 70 = 61		

Source: JRC.

The **B.7 score** is estimated according to Equation (165) and it is found to be equal to 70.9, which corresponds to a *Good* performance class (according to Figure 79), as reported in Table 126.

Table 126. Example of B.7 evaluation.

Indicator	**B.7.1**	**B.7.2**
Indicator score	77.5	61
B.7 score	= 0.6 · 77.5 + 0.4 · 61 = 70.9	
B.7 performance class	Good	
B.7 performance class score ($PCS_{B.7}$)	70	

Source: JRC.

4.11 Providing spatial coherence in planning and design (B.8)

4.11.1 Description and assessment

Providing spatial coherence in planning and design (B.8) KPI refers to the overarching goal of ensuring a consistent integration of spatial transformations in the context of urban development through the creation of harmony, unity, and order (SFOC, 2021). The process of integration requires complex actions, such as maintaining a balance among buildings, green spaces, and infrastructures, while respecting local identity and architectural principles. Additionally, revitalising and/or remediating industrial sites and contaminated land represents an opportunity for the sustainable urban development and reduces pressure on undisturbed land resources, thereby further enhancing spatial coherence and urban cohesion.

Providing spatial coherence in planning and design (B.8) KPI is evaluated through the following three indicators:

— *Spatial coherence and urban cohesion (B.8.1).*

— *Re-use of spaces and buildings (B.8.2).*

— *Green urban areas (B.8.3).*

B.8 and its three associated indicators result into scores ranging between 0 and 100; specifically, B.8 score is calculated according to Equation (171).

$$B.8 = \sum_{j=1}^{3}\left(w_{B.8.j} \cdot B.8.j\right) \Big/ \sum_{j=1}^{3}\left(w_{B.8.j}\right) = 0.4 \cdot B.8.1 + 0.3 \cdot B.8.2 + 0.3 \cdot B.8.3 \qquad (171)$$

Figure 91 provides the B.8 KPI performance classes and thresholds adopted in the self-assessment method. Hence, the four ranges of B.8 scores equal to $0 \leq$ B.8 $<$ 25, 25 $<$ B.8 $\leq$ 60, 60 $<$ B.8 $\leq$ 80, and 80$\leq$ B.8 $\leq$ 100 correspond to *Low*, *Acceptable*, *Good*, and *Excellent* performance class, respectively. While B.8 aspirational scores to attain the *Good* or the *Excellent* performance class remain desirable, it is highly recommended to reach at least an *Acceptable* performance class to maintain consistency with overarching urban development and sustainability objectives. This is particularly relevant in the situations where the official regulatory framework for spatial coherence is not available or not fully comprehensive.

Figure 91. B.8 performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.8 thresholds ($t_{B.8}$):	$0 \leq$		$t_{B.8,\ Acceptable}$ ≥ 25		$t_{B.8,\ Good}$ ≥ 60		$t_{B.8,\ Excellent}$ ≥ 80		≤ 100

Source: JRC.

The B.8 KPI and its corresponding indicators can be applied at **building**, **neighbourhood**, and **urban** scale, considering both **newbuild** and **renovation** projects with **residential** and **non-residential** use, according to the conditions in the following.

At **building scale**, B.8.1, B.8.2, and B.8.3 indicators can be implemented for new buildings (i.e. newbuild projects) and buildings undergoing reconstruction (i.e. renovation projects), as well as exterior spaces within the project designated area (this is particularly significant for B.8.3, which refers to green areas). However, **B.8.2 indicator applies to newbuild projects**, **only if the project is planned on a brownfield site**.

At **neighbourhood scale**, all indicators can be applied to a distinct neighbourhood within the urban context considering renovation project (e.g. projects focused on revitalizing existing neighbourhoods, often involving the redevelopment of underutilized spaces, with significant changes to the original characteristics of the buildings) and newbuild project (e.g. projects involving the creation of new neighbourhood areas, possibly on brownfield sites, with a mix of residential, commercial, and recreational spaces). Similarly to the building scale, B.8.2 indicator applies to newbuild projects, only if the project involves a brownfield site.

At **urban scale**, **B.8.1 is omitted.** Accordingly, B.8 evaluation relies only on B.8.2 and B.8.3 indicators. The reason to exclude B.81 is that the indicator, which is intended to ensure coherence and adaptation to the existing built environment and to promote urban planning integrating with the existing surroundings, is developed to assess individual buildings in their neighbourhood context and neighbourhoods in the broader context of districts or the city as a whole. The aim is to compare these elements with areas of similar characteristics, so the project assessor can decide whether to take into account administrative boundaries, natural boundaries of neighbourhood or other contextual factors. Given the complex nature of the urban fabric, which includes different zones such as business areas (with elevated building density and building heights), extensive green spaces and less urbanised peripheral areas, comparing a larger portion of a city with the city itself as a whole, or a whole city with adjacent areas is a challenge. While the underlying principles of this indicator are important for overarching, large-scale urban planning, its application as a specific indicator at urban scale may be less effective compared to its use at smaller spatial scales (i.e. building and neighbourhood scale).

4.11.2 Spatial coherence and urban cohesion (B.8.1)

Spatial coherence and urban cohesion (B.8.1) indicator focuses on the concept of spatial coherence (planning and design) that concerns the physical aspect of spatial transformation interventions, and relates to their actual level of integration into the urban patterns. It entails a consideration of the way a project correlates with the surrounding urban grain, mostly attaining to spatial/urban morphology aspects at the neighbourhood and urban scale. The urban grain represents the physical layout and spatial configuration of a locality, shaped by historical development and cultural heritage, in which coherence (a clear definition of coherence is provided in 'List of abbreviation and definition' section) emerges as the fundamental prerequisite for spatial quality within the urban fabric (Çalişkan and Mashhoodi, 2017).

The B.8.1 indicator assesses the degree of integration of a project within its respective environment. Any intervention should be undertaken with a thorough understanding and awareness of the existing place and its context at the relevant scale, from individual buildings to broader neighbourhood scales. In addition to essential form-based (normative) concepts in urban design referring to principles and regulations that guide the physical form of urban environments (e.g. density, compactness, continuity, connectivity, etc.), B.8.1 indicator takes into account material, typological, and aesthetic concepts, as well as function-related aspects (SFOC, 2021). B.8.1 aims to provide an understanding of the extent to which a project fits adequately into its context, highlighting the importance of harmonising architectural elements, preserving open spaces, and ensuring compatibility with the surrounding setting for a sustainable and integrated urban growth.

B.8.1 indicator is evaluated through the following five metrics, relying on the 'visual order' concept, which emerges from the 'consistency and complementarity in the scale, character, and arrangement of buildings, setbacks, street furniture, and landscaping' (Ewing et al., 2013), thus leading to a precise assessment of spatial quality:

- *Scale and proportion (SP).*
- *Open space connectivity (OSC).*
- *Density compatibility (DC).*
- *Integration with surroundings (IS).*
- *Coherence with local spatial and strategic planning (CP).*

B.8.1 score is evaluated as the weighted average of the aforementioned five metric scores (expressed as percentages), multiplied by 100 to obtain a dimensionless score ranging from 0 to 100, according to Equation (172).

$$B.8.1 = (0.2 \cdot SP + 0.2 \cdot OSC + 0.2 \cdot DC + 0.2 \cdot IS + 0.2 \cdot CP) \cdot 100 \quad (172)$$

Specificity of B.8.1 indicator lies in the fact that most of its metrics require a comparison of the project scale to be assessed with the area of common characteristics at a higher scale. Specifically, in the case of a new building project, a comparison with the neighbourhood scale needs to be considered, and in the case of a newbuild neighbourhood project, a comparison with the urban scale (e.g. a city district or the entire city, depending on the size of the city, based on own estimates) needs to be taken into account. Furthermore, the most adequate way to define the boundaries of the neighbourhood or urban scale (e.g. city district) needs to be identified by the users while proceeding with the self-assessment of a project. Boundaries can be established at a statistical-administrative level, or they can be based on protective measures, encompassing contact zones, historic urban landscapes or on functional or spatial considerations (including natural and geographic features). It is recommended to consider the area for which it is assumed that the project will achieve a correlation with the surrounding urban fabric, where aspects of spatial/urban morphology, aesthetic concepts, as well as function-related aspects at the neighbourhood and city level would be paramount.

Scale and Proportion (SP) metric evaluates the dimensions and proportions of buildings, aiming to ensure their consistency with the existing urban context. By promoting a coherent and aesthetically balanced built environment, this metric enhances the overall visual quality of the built landscape.

The *SP* score is based on the assessment of the average height of a building(s) located in the project designated area, as well as in the surrounding neighbourhood or urban area depending on the boundaries defined by the assessor to evaluate a building or neighbourhood scale project, respectively. Specifically, the SP score is calculated according to the scale and proportion deviation *($SP_{deviation}$)* sub-metric, which depends on the scale and proportion ratio (*SP_{ratio}*). The *SP_{ratio}* is evaluated as the ratio of the average height of a building(s) within the project designated area to the average height of the buildings within the surrounding neighbourhood/urban area, expressed as a percentage, according to Equation (173).

$$SP_{ratio} = \frac{Average\ height\ in\ designated\ area\ [m]}{Average\ height\ in\ neighbourhood/urban\ area\ [m]} \cdot 100\ [\%] \qquad (173)$$

The *$SP_{deviation}$* sub-metric relies on a maximum baseline score equal to 100 % and is evaluated as the difference in absolute value between the *SP_{ratio}* sub-metric score and 100 %, according to Equation (174). This means that the specific deviation from 100 % itself is disregarded, whether negative or positive, while the focus is solely on its absolute value to record the percentage above or below 100 %.

$$SP_{deviation} = |SP_{ratio} - 100\ \%| \qquad (174)$$

The *SP* score is then evaluated as the difference in absolute value between 100 % and the *$SP_{deviation}$* sub-metric score, expressed as a percentage, to obtain a score within the range of 0 to 100 %, according to Equation (175). This approach allows for quantifying and evaluating the degree of conformity in building heights between a designated area and its surrounding context. Higher scores of the SP metric denote a greater degree of similarity in terms of scale and proportion between the designated area and its surroundings.

$$\mathrm{SP} = |100\ \% - SP_{deviation}|\ [\%] \qquad (175)$$

Open Space Connectivity (OSC) metric promotes a well-connected and integrated urban fabric by examining the relationships among various open spaces (OS). Indeed, the spatial coherence also concerns the creation of human-scale spaces that are conducive to human activities, fostering a sense of community and connection, through a design that encourages social interaction and pedestrian-friendly environments (Gehl, 2010). The OSC metric assesses the project efficacy in preserving and linking accessible open areas and spaces within the urban context.

The *OSC* score is evaluated as the ratio of the number of open spaces extending beyond the project designated area to the total number of open spaces at the boundaries, expressed as a percentage, according to Equation (176). Specifically, in Equation (176), the *No of OS extending beyond the project designated area* refers to the number of areas not built upon or covered by buildings, also including parks, gardens, squares, or any undeveloped land, that extend beyond the boundaries of the project designated area, and the *Total No of OS at the boundaries* represents the total amount of open spaces at the boundaries of the project designated area.

$$OSC = \frac{No\ of\ OS\ extending\ beyond\ the\ project\ designated\ area}{Total\ No\ of\ OS\ at\ the\ boundaries\ of\ the\ project\ designated\ area} \cdot 100\ [\%] \qquad (176)$$

The density compatibility (DC) metric addresses growth management issues, such as urban sprawl, growth patterns, and phasing of developments that heavily influencing urban form. To overcome these issues, the DC metric focuses on one of the main policy tools for urban planning represented by the control of the floor area ratio (FAR) (Salat et al., 2014). The DC metric evaluates whether a project aligns with the density standards of the surrounding area ensuring that the density of buildings and structures fits within the context of the neighbourhood/urban area. The *DC* metric relies on the evaluation of the building(s) area in relation to the area of the project site it occupies, by comparing the project FAR with the fraction of the surrounding area. In general, the project FAR is expressed as the total floor area of a building(s) in relation to the area of the project site on which it is built, according to Equation (177).

$$Project\ FAR = \frac{Total\ floor\ area\ of\ the\ building(s)\ [m^2]}{Total\ area\ of\ the\ project\ site\ [m^2]} \quad (177)$$

The *DC* score relies on the project FAR deviation (*project* $FAR_{deviation}$) sub-metric, which depends on the project FAR ratio (*project* FAR_{ratio}). The *project* FAR_{ratio} is calculated as the ratio of the project FAR to the FAR in the neighbourhood/urban area, expressed as a percentage, according to Equation (178). To encourage a cohesive urban development, it is preferable that the density of new buildings closely align with the existing buildings in the surrounding area (Heymans et al., 2019). Ideally, the project FAR should be proportionate to the neighbourhood/urban area FAR. This indicates a balanced integration of the new development within the established urban fabric, promoting coherence and continuity in the overall built environment.

$$Project\ FAR_{ratio} = \frac{Project\ FAR}{FAR\ in\ neighborhood/urban\ area} \cdot 100\ [\%] \quad (178)$$

The *project* $FAR_{deviation}$ sub-metric relies on a maximum baseline score equal to 100 % and is evaluated as the difference in absolute value between the *project* FAR_{ratio} score and 100 %, according to Equation (179). This means that the specific deviation is disregarded from 100 % itself, whether negative or positive, while the focus is solely on its absolute value to record the percentage above or below 100 %.

$$Project\ FAR_{deviation} = |Project\ FAR_{ratio} - 100\ \%|\ [\%] \quad (179)$$

The *DC* score is evaluated consequently as the difference in absolute value between 100 % and the *project* $FAR_{deviation}$ sub-metric score, expressed as a percentage, to obtain a score within the range from 0 to 100 %, according to Equation (180). Higher scores of the DC metric denote a greater degree of similarity between the project designated area and its surroundings.

$$DC = |100\ \% - Project\ FAR_{deviation}|\ [\%] \quad (180)$$

Integration with surroundings (IS) metric evaluates the extent to which a project interacts adequately with its surrounding environment, including open landscapes and urban fabric. Various factors, such as colour, materials, and architectural design, are considered to ensure a seamless integration with the surroundings, emphasising the visual and aesthetic coherence. According to Fainstein and De Filippis (2015), understanding and preserving the urban grain are essential aspects for maintaining the unique identity and character of a city. Materials are also crucial in regard to the integration with surroundings, as they can evoke emotional responses and create a sense of place, while resonating with the local context, climate, and cultural identity (Broadbent, 1990).

The *IS* score is evaluated through three sub-metrics, i.e. *visual harmony and spatial relationships*, *transitional fluidity*, and *aesthetic coherence*, that are evaluated through visual assessment analyses and rely on the 'visual order' concept, which emerges from the consistency and complementarity in the scale, character, and arrangement of buildings, setbacks, street furniture, and landscaping (Ewing et al., 2013). This visual order ensures that all elements of a project work together to create a unified and aesthetically pleasing environment. The *Visual harmony and spatial relationships* sub-metric evaluates how well the layout and arrangement of built elements fit within the natural contours, elevations, and features of the landscape, whether the design maintains or enhances important views and sightlines, allowing for visual continuity and a sense of connection with the natural surroundings. The *Transitional fluidity* sub-metric measures how effectively the design facilitates a transition between the built environment and the open landscape. It focuses on two main aspects: (*i*) the gradual transition, intended as the presence of intermediary spaces or elements (e.g. terraces, patios, or gardens) that soften the boundary between the indoor and outdoor areas, and (*ii*) the accessibility indicating how easily people can move between the built environment and the open landscape, depending on pathways, doorways, and the overall flow. The *Aesthetic coherence* sub-metric evaluates how well the project respects and integrates with the historical context and spatial design of the neighbourhood/urban area, thus assessing how complementary the project architectural composition, typology, and materiality are with the surrounding buildings, ensuring visual harmony and cohesiveness.

The IS score is evaluated through the aforementioned three sub-metrics to which assign a rate based on a scale of points (i.e. 0 to 5), depending on the absence/presence and relevance degree of their specific features (based on the sub-metric definitions above) within a project design, according to the rationale in Table 127.

Table 127. Integration with surroundings (IS) metric score.

Sub-metric	**Score (points)**
Rate each sub-metric below according to a scale of points (0-5, where 0 corresponds to absence of features, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of features) and sum the three scores.	
Visual harmony and spatial relationships: evaluate whether and how the project design complements the natural features of the open landscape	0 to + 5
Transitional fluidity: evaluate whether and how the project design facilitates a seamless transition between the built environment and the open landscape	0 to + 5
Aesthetic coherence: evaluate whether and how the project design complements the architectural styles of neighbouring/urban area structures	0 to + 5
Integration with surroundings (IS) metric score = Σ sub-metric scores	**0 ≤ IS ≤ 15**

Source: JRC.

The IS score, expressed in points, needs to be transformed into a score, expressed as a percentage, ranging from 0 to 100 %, thus the IS final score is evaluated as the ratio of the number of points awarded to the maximum possible number of points (i.e. 15), expressed as a percentage, according to Equation (181).

$$IS = \frac{IS\ awarded\ number\ of\ points}{IS\ maximum\ number\ of\ points = 15} \cdot 100\ [\%] \qquad (181)$$

The IS final score indicates different degrees of the perceived integration of a project with surroundings, according to the following score ranges:

- The IS score ranging between 0 % and 20 % corresponds to a *very weak* perceived integration with surroundings (i.e. the project exhibits minimal to no discernible integration with its surroundings).
- The IS score ranging between 21% and 40% indicates a *weak* perceived integration with surroundings (i.e. project integration is below average, and shows significant shortcomings in meeting the specific features outlined within the sub-metrics).
- The IS score ranging between 41 % and 60% corresponds to a *moderate* perceived integration with surroundings (i.e. the project demonstrates moderate integration with its surroundings, meeting the basic features outlined within the sub-metrics).
- The IS score ranging between 61 % and 80 % is associated with a *strong* perceived integration with surroundings (i.e. the project integration with its surroundings is above-average, with positive performance in most of the features outlined in the sub-metrics while some refinements could further enhance the overall integration).
- The IS score ranging between 81 % and 100 % indicates a *very strong* integration with surroundings (i.e. the project exhibits overall integration and coherence with its surroundings in the assessed sub-metrics).

The *coherence with local spatial and strategic planning (CP)* metric relies on the coherence with local and regional policy and planning framework, thus referring to the alignment, synergy, and integration of spatial transformations with the policy and planning efforts (Couch et al., 2014). The CP metric assesses a project alignment and coherence with local spatial plans and broader strategic objectives, thus evaluating whether the project both contributes to informed decision-making, sustainable development practise and positively influences the overall development strategy of its designated area. The local spatial (i.e. land use) and strategic plans represent key actions that reflect the core values of urban stakeholders and demonstrate the functionality of the urban system the project is developed.

The CP score indicates the project compliance with relevant local spatial and strategic plans, evaluated as the ratio of the number of key priorities within these plans the project is aligned with to the total number of key priorities identified within these plans, expressed as a percentage, according to Equation (182).

$$CP = \frac{\begin{array}{c} No\ of\ key\ prioritites\ the\ project\ is\ compliant\ with \\ within\ the\ local\ spatial\ and\ strategic\ plans \end{array}}{\begin{array}{c} Total\ No\ of\ key\ priorities\ within \\ local\ spatial\ and\ strategic\ plans \end{array}} \cdot 100\ [\%] \tag{182}$$

Figure 92 shows the indicator thresholds used to associate indicator scores to performance classes for B.8.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement. Specifically, the *Low* performance class indicates significant shortcomings and metrics needing urgent improvement, the *Acceptable* one indicates moderate performance with potential for enhancement. The *Good* one demonstrates commendable performance with room for improvement, and the *Excellent* one indicates outstanding performance across all metrics.

Figure 92. B.8.1 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
B.8.1 thresholds ($t_{B.8.1}$):	$0 \leq$	$t_{B.8.1,\ Acceptable} \geq 25$	$t_{B.8.1,\ Good} \geq 55$	$t_{B.8.1,\ Excellent} \geq 80$	≤ 100

Source: JRC.

The B.8.1 score can be increased by enhancing the *open space connectivity* and elevating *green infrastructure* with the inclusion of small public parks and green corridors throughout the project to form a cohesive network of interconnected open spaces. The project design should prioritise interconnected pathways, visual continuity, and multifunctional green areas to encourage a sense of community, recreational opportunities, and environmental resilience (Bolund and Hunhammar, 1999, Pickett et al., 2001, Brussard and Pearlmutter, 2015). Other measures to improve B.8.1 score concern the improvement of the design that responds to complementarity with architectural composition, typology and materiality of neighbouring to also enhance the aesthetics coherence. Different configurations and massing options should be also explored to develop a design that incorporates stepped building heights. Furthermore, *coherence with local spatial and strategic planning* needs to be ensured, by conducting a detailed review of the existing local spatial and strategic plans relevant to the project area to align the project objectives with the key priorities identified by these plans. Finally, the proposed project development should contribute positively to the overarching goals of the community.

4.11.3 Re-use of spaces and buildings (B.8.2)

The *Reuse of spaces and buildings (B.8.2)* indicator assesses the extent to which existing buildings and spaces are reused or adapted for new purposes, thus proceeding with renovation projects and/or remediation of contaminated (i.e. dismissed industrial areas) or underutilised areas for newbuild projects, instead of using unsealed land, according to the paradigm of the no net land take (COM, 2021c). The indicator evaluates the practice of reusing space as an effective strategy to reduce urban sprawl and its associated environmental impacts while promoting the vitality and occupancy of neighbourhoods. The indicator recognises the importance of addressing areas in transition and/or deindustrialization, as the particular attention to these areas reflects a commitment to revitalising urban landscapes and promoting economic resilience, while improving the environmental performance of buildings and infrastructures in their entire life cycle (ESPON EGTC, 2020).

In general, B.8.2 indicator is evaluated through the following two metrics:

- *Re-development of contaminated areas (RCA).*
- *Re-development of functionally devalued areas (RDA).*

At **building scale**, B.8.2 indicator can be applied to newbuild projects only if the project to be self-assessed is carried out on a brownfield site. Thus, **in the case of a new building project on a greenfield site, B.8.2 is**

omitted from B.8 evaluation. Similarly, at **neighbourhood and urban scale,** B.8.2 indicator can be applied to a newbuild project only if the project involves areas of a brownfield site (beyond areas of a greenfield site).

The B.8.2 score, ranging from 0 to 100, is calculated as the weighted average of the aforementioned two metric scores (expressed as percentages), to be multiplied by 100, according to Equation (183). However, the *RCA* metric can be applied exclusively in case of projects concerning contaminated areas (i.e. industrial areas), thus **B.8.2 score evaluation for projects within non-contaminated areas** relies **exclusively on the *re-development of functionally devalued areas (RDA)* metric**, thus the RCA metric is omitted, according to Equation (184).

$$B.8.2 = (0.6 \cdot RCA + 0.4 \cdot RDA) \cdot 100 \tag{183}$$

$$B.8.2 = (1 \cdot RDA) \cdot 100 \tag{184}$$

The *re-development of contaminated areas (RCA)* metric assesses the extent to which pollution has been removed and activities have been undertaken to remediate and revitalise contaminated sites. It evaluates efforts to address contamination and restore the designated areas to a safe and usable condition.

The RCA score evaluates the re-developed area in square meters (m²), expressed as a percentage of the total contaminated area, according to Equation (185). RCA score represents the proportion of contaminated area that has undergone re-development or remediation efforts. The higher the score, the greater the level of successful re-development or remediation in relation to the total contaminated area.

$$RCA = \frac{Re\text{-}developed\ area\ [m^2]}{Total\ contaminated\ area\ [m^2]} \cdot 100 \tag{185}$$

Re-development of functionally devalued areas (RDA) metric evaluates the extent to which functionally devalued spaces within a given area have been revitalised and transformed to serve new and improved purposes. Functionally devalued areas refer to spaces within a built environment that have lost their original purpose or functionality, often due to neglect, deterioration, or changes in urban needs. These areas may include abandoned buildings, underutilised infrastructure, or not adequately maintained public spaces. RDA examines efforts to repurpose and enhance these areas, ensuring positive contribution to the overall quality and functionality of the environment.

The RDA score evaluates the re-developed area in square meters (m²), and expresses it as a percentage of the total functionally devaluated area (m²), according to Equation (186). The RDA score represents the proportion of functionally devalued area that has undergone re-development efforts. The higher the score, the greater the level of successful re-development in relation to the total devalued area.

$$RDA = \frac{Re\text{-}developed\ area\ [m^2]}{Total\ functionally\ devaluated\ area\ [m^2]} \cdot 100\ [\%] \tag{186}$$

Figure 93 shows the indicator thresholds used to associate indicator scores to performance classes for B.8.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement. The indicator score ranges, linked to the indicator performance class, categorise the overall re-use efforts into different levels of effective reused areas of spaces and buildings and elements relative to the total. Higher scores, corresponding to *Good* or *Excellent* performance classes, indicate a more comprehensive and successful re-use of the buildings, neighbourhoods and urban areas, while lower scores, corresponding to *Low* or *Acceptable* performance classes, suggest a lesser degree of re-use of buildings and areas.

Figure 93. B.8.2 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.8.2 thresholds ($t_{B.8.2}$):	$0 \leq$		$t_{B.8.2,\ Acceptable} \geq 20$		$t_{B.8.2,\ Good} \geq 50$		$t_{B.8.2,\ Excellent} \geq 80$		≤ 100

Source: JRC.

B.8.2 score can be enhanced by considering a *comprehensive renovation project* dealing with a thorough assessment of building infrastructures and systems to identify areas in need of renovation and invest in both upgrading utilities, HVAC systems and retrofitting structural components. Other measures regard *solid renovation strategies* focused on both the implementation of remediation strategies to effectively remove contamination and the use of advanced technologies, such as soil vapour extraction, bioremediation or chemical oxidation, to treat contaminants and restore the environmental quality.

4.11.4 Green urban areas (B.8.3)

Nature-based solutions, encompassing green infrastructure and ecosystem-based approaches, are fundamental to spatial coherence in landscape design for climate resilience. Spatial coherence in the green spaces design also involves integration of small-scale site planting within existing built environments (Klemm and McDonnell, 2013).

Based on the above, the *green urban areas (B.8.3)* indicator determines whether a project integrates easily accessible green areas and preserve and improve the quality of the place. The indicator also assesses whether a project is improved through dedicated solutions, such as promotion of spatial interventions that incorporate elements of the landscape, its vegetation and patterns, integration of existing natural features, and inclusion of new natural features in a multifunctional network that supports site quality and biodiversity.

B.8.3 indicator is evaluated through the three following metrics:

— *Increased areas under canopy cover (IC).*

— *Green infrastructure integration (GI).*

— *Biodiversity enhancement (BE).*

The B.8.3 score is calculated as the weighted average of the aforementioned three metric scores (expressed as percentages), multiplied by 100 to obtain a dimensionless score, ranging from 0 to 100, according to Equation (187).

$$B.8.3 = (0.\overline{3} \cdot IC + 0.\overline{3} \cdot GI + 0.\overline{3} \cdot BE) \cdot 100 \tag{187}$$

The *increased areas under canopy cover (IC)* metric evaluates the extent to which outdoor spaces within a building, neighbourhood, or urban scale project are covered by canopy or vegetation, underscoring the importance of integrating green infrastructure into urban developments to enhance environmental sustainability, improve air quality, mitigate urban heat island effects, and promote biodiversity. IC score estimates the area of outdoor spaces covered by canopy or vegetation within a project, expressed as a percentage of the total area of exterior spaces according to Equation (188).

$$IC = \frac{Total\ area\ of\ the\ exterior\ spaces\ covered\ by\ canopy\ [m^2]}{Total\ area\ of\ exterior\ spaces\ \ [m^2]} \cdot 100\ [\%] \tag{188}$$

Green infrastructure integration (GI) metric, also indicated as increased soil permeability, assesses the extent to which a project incorporates permeable soil surfaces within its exterior spaces, with the aim to mitigate issues related to urbanisation, such as storm water runoff, flooding, and soil erosion. The metric evaluates the degree of soil permeability within the project area, reflecting the project commitment to integrating green infrastructure and promoting sustainable land use practices. GI score evaluates the increased soil permeability by estimating the total area of permeable surfaces (i.e. unsealed soil), expressed as a percentage of area of unsealed soil in the total area of exterior spaces according to Equation (189).

$$GI = \frac{Area\ of\ unsealed\ soil\ [m^2]}{Total\ area\ of\ exterior\ spaces\ [m^2]} \cdot 100\ [\%] \tag{189}$$

The *biodiversity enhancement (BE)* metric assesses the effectiveness of biodiversity enhancement efforts within a project, aiming to quantify the introduction or promotion of native plants species, as well as to measure the increase in abundance or population size of native species. BE metric counts the total number of plant species that have been intentionally introduced or reintroduced into the project area. After collecting data on the abundance or population size of native species within the project area before and after biodiversity enhancement interventions, BE score estimates the introduction or increase of the post-intervention abundance (or population size), expressed as a percentage, compared to the pre-intervention abundance, according to Equation (190). However, BE maximum score cannot exceed 100 %.

$$BE = \frac{Post\text{-}intervention\ abundance - Pre\text{-}intervention\ abundance}{Pre\text{-}intervention\ abundance} \cdot 100\ [\%] \leq 100\ \% \tag{190}$$

In Equation (190), *post-intervention abundance* indicates the total number of plant species within the project area after the biodiversity enhancement intervention, thus including the species that have been intentionally introduced or reintroduced into the project area plus the existing ones, and *pre-intervention abundance* refers to the number of plant species within the project area before the biodiversity enhancement intervention.

Figure 94 shows the indicator thresholds used to associate indicator scores to performance classes for B.8.3. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement. Specifically, the *Low* performance class suggests significant shortcomings and the need for immediate attention and improvement of B.8.3 score, the *Acceptable* one indicates moderate performance with room for improvement, the *Good* one demonstrates a commendable level of achievement, and the *Excellent* one represents an exceptional performance across all metrics.

Figure 94. B.8.3 indicative indicator performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
B.8.3 thresholds ($t_{B.8.3}$):	$0 \leq$	$t_{B.8.3,\ Acceptable} \geq 25$	$t_{B.8.3,\ Good} \geq 50$	$t_{B.8.3,\ Excellent} \geq 75$	≤ 100

Source: JRC.

The B.8.3 indicator can achieve an higher score by *increasing the areas under canopy cover* and the density of vegetation by planting additional trees, shrubs, and greenery throughout outdoor spaces, and incorporating vertical greening elements, such as living walls and vertical gardens to maximise canopy cover within constrained areas. Other solutions concern the *green infrastructure integration* to increase soil permeability. Specifically, the proportion of permeable surfaces can be increased by retrofitting existing hardscaped areas with permeable pavement, gravel pathways, and porous materials. Bioswales and rain gardens can be implemented to capture and filter storm water runoff, improve soil permeability and enhance water quality. Moreover, natural drainage features, such as swales and berms, can be incorporated to direct rainwater into vegetated areas and promote infiltration. Further suggestions concern the *biodiversity enhancement* by expanding the variety of native plant species into the project area to create a diverse and resilient ecosystem that support a wide range of wildlife. Habitat restoration initiatives, such as the creation of wetlands, meadows, and wildlife corridors, can also be implemented to provide critical habitats for native species.

4.11.5 Example (B.8)

The example refers to a renovation project aimed to transform a mixed-use neighbourhood, accounting for a surface (i.e. project site) equal to 4000 m^2, within a larger urban area into an ecologically sustainable and cohesive environment. Focusing on sustainability aspects, the project integrates various initiatives to enhance the neighbourhood infrastructure, increase cohesion, and introduce green spaces into a high-density environment. Starting with a brownfield redevelopment project, the urban planning aim to repurpose a former industrial building on a contaminated site. Environmental engineers will conduct assessments and soil testing to determine the extent of contamination. The project objective is to remediate the site, renovate the existing building, and convert it into a mixed-use space with commercial and residential units. Simultaneously, the project also envisions the creation of a new green city block, connecting major streets. Street façades will be restrained, while greened buildings, a promenade, and a park will be developed within the block. The project will feature various residential typologies alongside green environments and a vertical park. A variety of plants will be integrated throughout the site and building floors, supported by an irrigation and drainage system. Sustainability of the greenery will be ensured through a detailed horticultural project, with plant maintenance being the responsibility of the joint maintenance service of the city block.

The project is classified as a neighbourhood and renovation project according to scale and type, respectively, whereas the residential use is considered as it is identified as the main use of the project (please note that B.8 score evaluation is not affected by the project main use).

The evaluation of B.8 depends on the scores of B.8.1, B.8.2, and B.8.3 indicators, thus their estimation was first carried out.

The **B.8.1 score** is evaluated through the following five metrics: (*i*) scale and proportion, (*ii*) open space connectivity, (*iii*) density compatibility, (*iv*) integration with the surroundings, and (*v*) coherence with local spatial and strategic plans.

Scale and proportion (SP) metric is evaluated following the estimation of the $SP_{deviation}$ sub-metric score that relies on the SP_{ratio} score. The SP_{ratio} score evaluation is based on the assumption that existing buildings with the following heights: 60 m, 53 m, 50 m, 55 m, 57 m, and 55 m[5], are located in the designated area of the neighbourhood scale project. Hence, the average height of buildings in the designated area is estimated equal to 55 m. In order to define the broader urban area delimitation to which the designated area of the neighbourhood scale project needs to be compared to, the existing boundaries established at the statistical-administrative level were chosen, since the characteristics of the project largely coincide with the characteristics of the buildings located within the city district (administrative division). The average height of all buildings in the surrounding neighbourhood area (i.e. city district area) is 35 m. Based on these data, the SP_{ratio} score is estimated equal to 160 %, using Equation (173), as reported in Equation (191).

$$SP_{ratio} = \frac{55 \text{ m}}{35 \text{ m}} \cdot 100 = 160 \ \% \tag{191}$$

The $SP_{deviation}$ sub-metric score is evaluated using Equation (174) and it is found to be equal to an absolute value of 60 %, as reported in Equation (192).

$$SP_{deviation} = |160 \ \% - 100 \ \%| = 60 \ \% \tag{192}$$

The SP score is evaluated using Equation (175) and it is estimated equal to 40 %, as reported in Equation (193), pointing out the level of scale and proportion of the project in the designated area compared to the surrounding neighbourhood considered as boundaries. The SP score suggests that the scale and proportion of the buildings in the designated area are partially aligned with the ones in the surrounding neighbourhood. However, the SP_{ratio} score indicates that the buildings in the designated area are taller on average, potentially affecting the visual coherence of the urban landscape.

[5] Data are provided solely for the purpose of clarifying the evaluation of the metric score and do not serve as benchmarks or standards.

$$SP = |100\ \% - 60\ \%| = 40\ \% \quad (193)$$

Open space connectivity (OSC) metric is evaluated based on the following two sub-metrics: (*i*) the number of open spaces extending beyond the project designated area is equal to 12 (including small parks, community gardens, pedestrian walkways, public squares, etc.), while (ii) the total number of open spaces at the boundaries of the project designated area is equal to 15. From the Equation (176), the OSC score is estimated equal to 80 %, as reported in Equation (194).

$$\mathrm{OSC} = \frac{12}{15} \cdot 100 = 80\ \% \quad (194)$$

The OSC score points out that 80 % of the open spaces extend beyond the project area boundaries. This high percentage suggests strong connectivity between the project open spaces and the ones located in the surrounding areas, indicating that the project open spaces are well-integrated with the broader urban environment, facilitating movement and accessibility throughout the neighbourhood. This high connectivity fosters a sense of continuity and coherence in the urban landscape, promoting pedestrian flow and community engagement across different areas of the neighbourhood.

Density compatibility (DC) metric is evaluated following the estimation of the *project* $FAR_{deviation}$ sub-metric score that relies on the *project* FAR_{ratio} score. To evaluate the *project* FAR_{ratio} score, the following data needed to first estimate the project FAR are considered: the total floor area of the buildings within the designated project area is equal to 12000 $m^2$and the total area of the project site is equal to 4000 m^2. Hence, the project FAR score is calculated using Equation (177) and resulting into a value equal to 3, as estimated through Equation (195).

$$Project\ FAR = \frac{12\ 000\ m^2}{4\ 000\ m^2} = 3 \quad (195)$$

The FAR in the city district area is equal to 2; therefore, the *project* FAR_{ratio} score is evaluated using Equation (178), resulting equal to 150 %, as reported in Equation (196).

$$Project\ FAR_{ratio} = \frac{3}{2} \cdot 100 = 150\ \% \quad (196)$$

The *project* $FAR_{deviation}$ sub-metric score is evaluated using Equation (179) and it is found to be equal to an absolute value of 50 %, as reported in Equation (197).

$$Project\ FAR_{deviation} = |150\ \% - 100\ \%| = 50\ \% \quad (197)$$

The DC score is evaluated using Equation (180) and it is found to be equal to 50 %, as reported in Equation (198), indicating a medium level of compliance in terms of density with the surrounding area.

$$DC = |100\ \% - 50\ \%| = 50\ \% \quad (198)$$

The *integration with surroundings (IS)* metric is first evaluated in points based on the absence/presence and degree of relevance of the specific features related to the three sub-metrics, i.e. *visual harmony and spatial relationship, transitional fluidity,* and *aesthetic coherence,* within the project (Table 127), as reported in the following, leading to the IS score in points equal to 12 (out of 15), as reported in Table 128. Specifically, regarding the *Visual harmony and spatial relationships* sub-metric, the project design effectively integrates with the natural features of the open landscape, ensuring visual harmony and the incorporation of green spaces with a high-density environment enhances the overall aesthetic appeal. Regarding the *Transitional fluidity* sub-metric, the project design prioritises fluidity, providing a transition between the built environment and the open landscape; walkways, green corridors, and thoughtful design contribute to integrated space. However, there remains potential for further refinement to enhance the permeability and connectivity of spaces, which could elevate the overall fluidity and user experience. Regarding the *Aesthetic coherence* sub-metric, the project design is in harmony with neighbouring structures, as the project not only complements but also brings additional value to the aesthetic coherence of the area by introducing contemporary sustainable design practices - greened façades and unified design elements, complementing and enhancing the architectural vernacular of the neighbourhood.

Table 128. Example of *integration with surroundings (IS)* evaluation.

Sub-metric	**Score (points)**
Rate each sub-metric below according to a scale of points (0-5, where 0 corresponds to absence of feature, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of features) and sum the three scores.	
Visual harmony and spatial relationships: evaluate how the project design complements the natural features of the open landscape.	+ 4 (strong)
Transitional fluidity: evaluate how the project design facilitates a seamless transition between the built environment and the open landscape.	+ 3 (moderate)
Aesthetic coherence: evaluate how the project design complements the architectural styles of neighbouring/urban area structures.	+ 5 (very strong)
Integration with surroundings (IS) metric score = Σ sub-metric scores	**IS = 12**

Source: JRC.

The IS score, expressed in points, is transformed into the IS final score by using Equation (181), thus estimating equal to 80 %, as provided through Equation (199). According to score ranges corresponding to different degree of the perceived integration (Section 4.11.2), the IS score indicates a strong perceived integration of the project with its surroundings, suggesting that the project exhibits above-average integration with positive performance of the features across most sub-metrics.

$$IS = \frac{12}{15} \cdot 100 = 80\ \% \tag{199}$$

Coherence with local spatial and strategic planning metric is evaluated based on the following aspects. A local spatial planning document along with a strategic plan outlining the city development initiatives is provided at community level. Five key priorities were identified within this plan: (*i*) sustainable infrastructure development ensuring that the project is consistent with plans for sustainable infrastructure development, such as energy efficient utilities and green technologies; (*ii*) mixed land use to comply with zoning regulations to encourage mixed-use areas to promote a mix of residential, commercial and recreational areas; (*iii*) preservation of green space to prioritise the preservation of green space and ensure that the project unions well with existing parks or integrates new green space; (*iv*) affordable housing: coordinating with affordable housing plans to meet the diverse housing needs of the community, and (*v*) transit-oriented development: adherence to strategies to promote transit-oriented development, improving accessibility, and reducing reliance on private vehicles. The project aligns with all the five key priorities identified by the local spatial and strategic plan, as it includes sustainable infrastructure, mixed-use zoning, green space preservation, affordable housing, and transit-oriented development. Hence, the CP score is estimated using Equation (182) and resulting into a value equal to 100 % that indicates a very strong level of coherence with the local spatial (i.e. land use) and strategic plans, as reported through Equation (200).

$$CP = \frac{5}{5} \cdot 100 = 100\ \% \tag{200}$$

Having evaluated the score of each metric, B.8.1 score is calculated according to Equation (172), resulting into a value equal to 70, corresponding to the indicative *Good* performance class (Figure 92), as reported in Table

129. The project exhibits commendable connectivity with its surroundings and coherence with planning documents, although it does not fully meet scale and proportion, as well as density compatibility standards. However, the project excels in aligning with local planning priorities and demonstrates cohesive integration with its surroundings, indicating a high level of overall coherence.

Table 129. Example of B.8.1 evaluation.

Metric	SP	OSC	DC	IS	CP
Metric score	40 %	80 %	50 %	80 %	100 %
B.8.1 score	= (0.2 · 40 % + 0.2 · 80 % + 0.2 · 50 % + 0.2 · 80 % + 0.2 · 100 %) · 100 = 70				
B.8.1 performance class	(Good)[1]				

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

The **B.8.2 score** is evaluated through the following two metrics: (*i*) re-development of contaminated areas and (*ii*) re-development of functionally devalued areas. In case a project involves a brownfield area without contamination, only the redevelopment of functionally devalued areas metric is considered. In the proposed example a total area equal to 1000 m^2 within the project site area was found to be contaminated, thus both metrics applies to the example.

Re-development of contaminated areas (RCA) metric is estimated based on the assumption that remediation strategies of the contaminated area, such as soil excavation to reduce the risks of contamination, were carried out by specialists. Following these works, an area equal to 800 m^2 out of the total 1000 m^{2}of the formerly contaminated area, was successfully remediated. Hence, RCA score is estimated using Equation (185) and results into a value equal to 80 %, according to Equation (201), which indicates a high percentage of the contaminated area within the building footprint successfully remediated.

$$RCA = \frac{800\ m^2}{1000\ m^2} \cdot 100 = 80\ \% \quad (201)$$

Re–development of functionally devalued areas (RDA) metric is estimated based on the following sub-metrics. A total area equal to 1000 m^2 was found to be functionally devalued, following the architects and urban planners' assessment concerning the existing condition of the former industrial building to be renovated and the identification of functionally devalued spaces, such as deteriorating infrastructure and vacant spaces. Plans for renovating the building, improving the infrastructure and adapting the contemporary needs were developed leading to the successful transformation of an area equal to 900 m^2 out of the total functionally devalued area of 1000 m^2. Hence, RDA score is estimated using Equation (186) and results into a value equal to 90 %, as reported in equation (202), which indicates a very high percentage of the functionally devalued area within the building successfully re-developed through renovation efforts.

$$RDA = \frac{900\ m^2}{1000\ m^2} \cdot 100 = 90\ \% \quad (202)$$

Having evaluated the score of each metric, B.8.2 score is calculated according to Equation (183), resulting into a value equal to 84, corresponding to the indicative *Excellent* performance class (Figure 93), as reported in Table 130. The evaluation of B.8.2 emphasises the greater importance of remediating contaminated areas, while still recognising the significance of improving functionally devalued areas. B.8.2 score indicates a high level of success in revitalising both contaminated and functionally devalued areas within the project.

Table 130. Example of B.8.2 evaluation.

Metric	RCA	RDA
Metric score	80 %	90 %
B.8.2 score	= 0.6 · 80 % + 0.4 · 90 %) · 100 = 84	
B.8.2 performance class	(Excellent) [1]	

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

The **B.8.3 score** is evaluated through the three following metrics: (*i*) increased areas under canopy, (*ii*) green infrastructure integration, and (*iii*) biodiversity enhancement.

Increased areas under canopy (IC) cover metric is evaluated based on the assumption that the integration of trees, shrubs, and other vegetation in the exterior spaces of the project area is designed to increase canopy cover. Specifically, the plan foresees to cover by canopy an area equal to 500 m^2 out of the total area of the exterior spaces of 1000 m^2. Hence, the IC score is estimated using Equation (188) and results into a value equal to 50 %, as reported in Equation (203), indicating the percentage of the total area of the exterior spaces which will be covered by lush canopy, thus creating an oasis amidst the urban landscape.

$$IC = \frac{500\ m^2}{1000\ m^2} \cdot 100 = 50\ \% \tag{203}$$

Green infrastructure integration (GI) metric is evaluated by relying on the assumption that the project provides for the incorporation of permeable surfaces, such as green roofs, permeable pavement, and landscaped areas to increase soil permeability. Specifically, the project foresees a total area of unsealed soil equal to 300 m^2 out of a total area of exterior spaces of 1000 m^2. Hence, the GI score is calculated using Equation (189) and results into a value equal to 30 %, according to Equation (204), indicating the percentage of exterior spaces ensured to be unsealed soil to increase soil permeability.

$$GI = \frac{300\ m^2}{1000\ m^2} \cdot 100 = 30\ \% \tag{204}$$

Biodiversity enhancement metric is calculated based on the increase of native plants within the project area. With the introduction of 20 new plant species, there has been a notable increase in their total number, as only 10 plant species were present prior to the project development. Hence, the post-intervention abundance corresponds to a total number of 30 plant species, whereas the pre-intervention abundance is equal to 10. Based on these sub-metrics, BE score is estimated using Equation (190), resulting into a 200% increase in abundance compared to the original number of plant species, as reported in Equation (205). This initiative significantly enhances the ecological richness and resilience of the site. However, BE maximum score cannot exceed 100 %, thus the score is set equal to 100 %. By creating habitat diversity and supporting native flora and fauna, the project contributes to the overall health of urban ecosystems.

$$BE = \frac{30 - 10}{10} \cdot 100 = 200\ \% \ \rightarrow \mathrm{BE} = 100\ \% \tag{205}$$

Having evaluated the score of each metric, B.8.3 score is calculated according to Equation (187), resulting into a value equal to 59.9, corresponding to the indicative *Good* performance class (Figure 94), as reported in Table 131. The project demonstrates an overall integration of green areas, thus preserving and improving the quality of the place.

Table 131. Example of B.8.3 evaluation.

Metric	**IC**	**GI**	**BE**
Metric score	50 %	30 %	100 %
B.8.3 score	= $(0.\overline{3} \cdot 50\ \% + 0.\overline{3} \cdot 30\ \% + 0.\overline{3} \cdot 100\ \%) \cdot 100 = 59.9$		
B.8.3 Performance class	(Good)[1]		

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

Having evaluated the three indicators, the **B.8 score** is estimated using Equation (171) and it is found to be equal to 71.1, which corresponds to the *Acceptable* performance class (according to Figure 91), as reported in Table 132. The B.8 performance class attained demonstrates that the project exhibits a good effort in enhancing spatial coherence, reusing spaces and buildings, and integrating green urban areas. While there are areas for improvement, the project shows promise in transforming the neighbourhood into a sustainable and cohesive urban environment.

Table 132. Example of B.8 evaluation.

Indicator	**B.8.1**	**B.8.2**	**B.8.3**
Indicator score	70	84	59.9
B.8 score	= 0.4 · 70 + 0.3 · 84 + 0.3 · 59.9 = 71.1		
B.8 performance class	Good		
B.8 performance class score ($PCS_{B.8}$)	70		

Source: JRC.

4.12 Improving preservation of cultural and natural heritage (B.9)

4.12.1 Description and assessment

Improving preservation of cultural and natural heritage (B.9) KPI emphasises the importance of safeguarding and enhancing the protection of both cultural and natural assets for the benefit of present and future generations. Cultural heritage (a clear definition is provided in the 'List of abbreviations and definitions' section) gives evidence of the many types of human activities, historic events and evolutions, artistic creations, social institutions and technical achievements. Natural heritage provides evidence of the diverse types of ecological processes, evolutionary developments, geological formations, biodiversity, and interactions between ecosystems. This goal involves a multi-sectoral approach aimed at ensuring the responsible project development, conservation and sustainable design of places, artefacts, ecosystems and landscapes of cultural and environmental significance. Uses of - and interventions on - cultural heritage must respect and keep the character of a place and its values. Maintaining authenticity and integrity (clear definitions are provided in the 'List of abbreviations and definitions' section) is of great importance, even in cases of compatible and respectful re-use, so that future generations would continue to have access to the full richness of the existing heritage (Commission SWD, 2019; Dimitrova et al., 2020). Natural and cultural heritage can contribute to, and are also crucial enablers of resilience, adaptation, and sustainable development. Through smart renovation and transformation, heritage sites can find new, mixed or extended uses. As a result, their social, environmental and economic value is increased, while their cultural significance is enhanced. However, conservation actions should preserve and reveal the aesthetic and historic value of a building/site (Council of Europe, 2021), based on respect for original materials and authentic documents. The valid contributions to a monument/cultural building from all historical periods should be recognised and respected. Replacements of missing parts should be integrated harmoniously with the whole, but at the same time must be distinguishable from the original, so that restoration does not falsify the artistic or historic evidence (ICOMOS, 1964). Cultural heritage is inherently interdependent, as it is continuously redefined through human activity, thus not being a static, unchanging entity, and emphasising the relationship to the spatial environment.

The B.9 KPI focusing on the enhancement and protection of cultural and natural heritage is assessed through the three following indicators, tailored to different contexts depending on the statutory protection or not of the project to be assessed:

— *Historical fabric preservation (B.9.1)*, which targets statutory protected historical environments, city landscapes, and heritage sites.

— *Integrated heritage/natural landscape conservation (B.9.2)*, which applies to statutory protected natural landscape contexts.

— *Improving preservation of cultural and natural heritage in renovated buildings (B.9.3)*, which addresses renovation projects that are not statutory protected, but have historical and cultural significance.

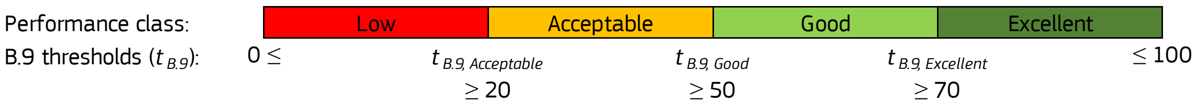
The B.9 score, ranging from 0 to 100, is calculated differently depending on whether the evaluation refers to renovation projects of buildings/neighbourhoods with statutory protection, or without statutory protection but with historical and cultural value contributing to heritage preservation and revitalisation. Specifically, if a cultural and natural heritage project is **statutory protected**, the B.9 score evaluation relies on **B.9.1 and B.9.2 indicators** (i.e. B.9.3 indicator is omitted), according to Equation (206). Conversely, if a cultural and natural heritage project is **not statutory protected**, B.9 score evaluation only depends from **B.9.3 indicator** (i.e. B.9.1 and B.9.2 indicators are omitted), according to Equation (207).

$$B.9 = \sum_{j=1}^{2} \left(w_{B.9.j} \cdot B.9.j \right) \Big/ \sum_{j=1}^{2} \left(w_{B.9.j} \right) 0.6 \cdot B.9.1 + 0.4 \cdot B.9.2 \quad (206)$$

$$B.9 = w_{B.9.j} \cdot B.9.j = 1 \cdot B.9.3 \quad (207)$$

Figure 95 provides the B.9 KPI performance classes and thresholds adopted in the self-assessment method. Hence, the four ranges of B.9 scores, equal to $0 \leq$ B.9 < 20, 20 < B.9 $\leq$ 50, 50 < B.9 $\leq$ 70, and 70 $\leq$ B.9 $\leq$ 100, are associated with the *Low, Acceptable, Good* and *Excellent* performance class, respectively. While B.9 scores to attain the *Good* or the *Excellent* performance class are greatly desirable, meeting the *Acceptable* performance class leastwise is highly recommended to ensure that the project at least contributes to the overall objective of respecting and preserving the character of heritage places and values.

Figure 95. B.9 performance classes and thresholds.



Source: JRC.

The B.9 KPI and its corresponding indicators are applicable **exclusively to cultural heritage** projects (i.e. B.9.1 and B.9.2 for statutory protected projects, and B.9.3 for non-statutory protected projects) at both **building** and **neighbourhood** scale, including **exclusively renovation projects** concerning both **residential** and **non-residential** use.

Specifically, at both building and neighbourhood scale, the B.9.1 indicator can act as a guideline to ensure that restoration efforts align with the principles of historical fabric preservation, thus it can be applied for historic building restoration projects and/or cultural heritage building conservation, as well as conservation of historical/cultural heritage neighbourhoods. The B.9.2 indicator can be applied to conservation or restoration planning for heritage sites that involves integrated approaches to landscapes, including efforts to protect or restore original design elements, plant species, and features that contribute to the historical character of the green spaces within the project. Hence, B.9.2 focuses on both building and neighbourhood renovation projects within a natural landscape or including natural spaces with historic significance (e.g. historic gardens, parks, green areas) undergoing revitalisation.

The B.9.3 indicator is applied to renovation projects that focus on the restoration and preservation of historic buildings and neighbourhoods, that are not statutory protected (conversely to B.9.1 and B.9.2), but hold architectural and/or cultural value. Examples may include historic building renovation, adaptive reuse initiatives focusing on renovation projects that repurpose existing buildings for new uses while retaining their original character and architectural elements, neighbourhood re-development projects focused on revitalising neighbourhoods or districts, where preserving key architectural features and maintaining the area cultural identity is essential.

4.12.2 Historical fabric preservation (B.9.1)

The *historical fabric preservation (B.9.1)* indicator assesses the holistic preservation efforts within a heritage project to maintain the authentic character and visual integrity of historical structures and surroundings, encompassing the preservation of various aspects, such as patina, original structural elements and historical infrastructure materials, and chromatic traditions.

The B.9.1 indicator that **only** applies to **statutory protected cultural heritage** is evaluated through the following four metrics:

— *Preserved patina (PP).*

— *Preserved original/historic structural elements (PSE).*

— *Preserved original/historic openings (PO).*

— *Heritage value (HV).*

The B.9.1 score is calculated as the weighted average of the scores of the aforementioned four metrics (expressed as percentages), multiplied by 100 to obtain a dimensionless score ranging from 0 to 100, according to Equation (208).

$$B.9.1 = (0.25 \cdot PP + 0.25 \cdot PSE + 0.25 \cdot PO + 0.25 \cdot HV) \cdot 100 \quad (208)$$

Preserved patina (PP) metric serves as a tool to maintain history and the cultural diversities of buildings and neighbourhoods. It evaluates the extent to which existing materials and elements have been saved and cleaned to display their age or used appearance contributing to the preservation of the historical patina (a clear definition of patina is provided in the 'List of abbreviations and definitions' section).

The PP score evaluates the ratio of the area of preserved patina, typically involving the building façades, in square meters (m^2) to the total area of the external walls of a building in square meters (m^2), expressed as a percentage, according to Equation (209).

$$PP = \frac{Area\ of\ presevered\ patina\ [m^2]}{Total\ area\ of\ external\ walls\ of\ building\ [m^2]} \cdot 100\ [\%] \quad (209)$$

Preserved original/historic structural elements (PSE) metric deals with the conservation of original or historic structural elements of a building, including perimeter and inner structural walls, floors, and roofs. The metric evaluates the extent to which the original or historic structural elements are preserved, indicating the degree of conserving the historical integrity and authenticity of the structure.

The PSE score is calculated as the ratio of the area of preserved original or historic structural elements (i.e. walls, floors, roofs) in square meters (m^2) to the total floor area of the building in square meters (m^2), expressed as a percentage, according to Equation (210).

$$PSE = \frac{Area\ of\ preserved\ structural\ elements\ [m^2]}{Total\ floor\ area\ of\ building\ [m^2]} \cdot 100\ [\%] \quad (210)$$

Preserved original/historic openings (PO) metric examines the preservation or replacement of original/historic openings, such as windows, shutters, and doors. Specifically, the metric evaluates the extent to which original or historic openings have been maintained, properly compared to the total number of openings, indicating the degree of preservation.

The PO score estimates the ratio of the number of preserved original or historic openings to the total number of openings, expressed as a percentage, according to Equation (211).

$$PO = \frac{Number\ of\ preserved\ openings}{Total\ number\ of\ openings} \cdot 100\ [\%] \quad (211)$$

Heritage value (HV) metric assesses comprehensively a heritage site, considering its historical, aesthetic, and architectural attributes, which can be summarised in the following three sub-metrics, i.e. *representativeness*, *ambient value*, and *architectural value*.

The HV score is evaluated through the aforementioned three sub-metrics to which assign a rate based on a scale of points (i.e. 0 to 5), depending on the absence/presence and relevance degree of their specific features within a project, according to the rationale in Table 133.

Table 133. Heritage value assessment (HVA) metric score.

Sub-metric	**Score (points)**
Rate each sub-metric below according to a scale of points (0-5, where 0 corresponds to absence of feature, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of features) and sum the three scores)	
Representativeness: evaluate how the heritage site represents a particular period, style, or cultural aspect?	0 to + 5
Ambient value: evaluate the heritage site environmental and aesthetic qualities, consider its natural surroundings, landscape, and overall atmosphere.	0 to + 5
Aesthetic coherence: evaluate the architectural significance, innovation, and craftsmanship of the buildings within the heritage site.	0 to + 5
Heritage value (HV) metric score = Σ sub-metric scores	**0 ≤ HV ≤ 15**

Source: JRC.

The HV score, expressed in points, needs to be transformed into a score, expressed as a percentage, ranging from 0 % to 100 %, thus the HV final score is evaluated as the ratio of the number of points awarded to the maximum possible number of points (i.e. 15), expressed as a percentage, according to Equation (212).

$$HV = \frac{HV\ awarded\ number\ of\ points}{HV\ maximum\ number\ of\ points = 15} \cdot 100\ [\%] \qquad (212)$$

The HV final score indicates different degrees of the perceived heritage value, according to the following score ranges:

— The HV score ranging between 0 % and 20 % corresponds to very low perceived heritage value (i.e. the heritage site shows minimal representation of its intended period, style, or cultural aspect, with minimal environmental and aesthetic qualities, and architectural features lack significance and craftsmanship).

— The HV score ranging between 21 % and 40 % indicates a *low* heritage value (i.e. the heritage site representation of its intended period, style, or cultural aspect is limited, and environmental and aesthetic qualities are below average).

— The HV score ranging between 41 % and 60 % corresponds to *moderate* perceived heritage value (i.e. the heritage site moderately represents its intended period, style, or cultural aspect, possesses moderate environmental and aesthetic qualities, and while architectural features are satisfactory, there is room for improvement in terms of innovation and craftsmanship).

— The HV score ranging between 61 % and 80 % is associated to a *strong* perceived heritage value (i.e. the heritage site effectively represents its intended period, style, or cultural aspect, exhibits high environmental and aesthetic qualities, creating a positive overall atmosphere, and architectural features are significant).

— The HV score ranging between 81 % and 100 % indicates a *very strong* perceived heritage value (i.e. the heritage site excellently represents its intended period, style, or cultural aspect, excels in environmental and aesthetic qualities, creating an exceptional overall atmosphere, and architectural features are of outstanding significance).

Figure 96 shows the indicator thresholds used to associate indicator scores to performance classes for B.9.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 96. B.9.1 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.9.1 thresholds ($t_{B.9.1}$):	0 ≤		$t_{B.9.1,\ Acceptable}$ ≥ 20		$t_{B.9.1,\ Good}$ ≥ 50		$t_{B.9.1,\ Excellent}$ ≥ 70		≤ 100

Source: JRC.

The B.9.1 score can be increased by enhancing the *historical material conservation* through the implementation of conservation practices (ICOMOS, 1964) that prioritise the preservation of historical materials, façades, or surfaces with patina, utilising specialised techniques and materials to retain and protect existing patina, and contributing to the authenticity and historical character of the built environment. Other measures to improve the B.9.1 score deal with the application of *adaptive reuse methods* to retain original and historic structural elements for new functional purposes to preserve their physical integrity and also add value to the contemporary use of the space. Furthermore, the *integration of the preserved original or historic structural elements* into the design can be promoted, thus presenting the preserved structural elements as distinctive features aimed to conserve the historical character and contribute to a sense of continuity with the past.

4.12.3 Integrated heritage/natural landscape conservation (B.9.2)

The *integrated heritage landscape conservation (B.9.2)* indicator assesses the combined efforts in preserving and restoring both traditional cultivated landscapes and original, historic green areas. It focuses on the coexistence of culturally significant cultivation practices and the revitalisation of green spaces, fostering an integrated approach to heritage conservation (i.e. the conservation of landscape qualities and sustainable use of natural resources, landscapes, and ecosystems). The indicator emphasises the importance of considering environmental factors in design and construction, with a view to minimising the ecological impact of human activities. The aim is to carry out actions to conserve and maintain the significant or characteristic features of a landscape, justified by its heritage value derived from its natural configuration and/or from human activity (Council of Europe, 2003; Commission SWD, 2019).

The B.9.2 indicator that **only** applies to **statutory protected natural heritage** is evaluated through the following two metrics:

- Traditional cultivated landscape preservation and restoration (TLPR).
- Preserved or recovered original, historic green spaces (PRGS).

The B.9.2 score is estimated as the weighted average of the scores of the aforementioned two metrics (expressed as percentages), multiplied by 100, to obtain a dimensionless score ranging from 0 to 100, according to Equation (213).

$$B.9.2 = (0.5 \cdot TLPR + 0.5 \cdot PRGS) \cdot 100 \tag{213}$$

Traditional cultivated landscape preservation and restoration (TLPR) metric evaluates the efforts to conserve or revive traditional landscapes. It considers sustainable cultivation practices, preservation of cultural heritage, and maintain ecological balance. The goal is to ensure the continuity of traditional cultivating methods while promoting environmental sustainability and cultural identity. TLPR metric assesses the overall extent of traditionally cultivated landscapes that have been conserved or revitalised in a project.

The TLPR score computes the proportion of the preserved or revitalised area relative to the entire expanse, i.e. total area of the project site, expressed as a percentage, according to Equation (214).

$$TLPR = \frac{Preserved\ or\ revitalised\ area\ [m^2]}{Total\ area\ of\ project\ site\ [m^2]} \cdot 100\ [\%] \tag{214}$$

Preserved or recovered original, historic green spaces (PRGS) metric assesses the protection or regeneration of urban green spaces, both public and private, with a focus on preserving autochthonous and endemic greenery. It includes different green areas, such as parks, gardens, botanical gardens, and greenhouses. The aim is to maintain or restore the original character and biodiversity of these green areas, contributing to a healthier and more sustainable environment.

The PRGS score estimates the ratio of the area of preserved or recovered original, historic green areas in a project site, to the total area of the project site, expressed as a percentage, according to Equation (215).

$$PRGS = \frac{Preserved\ or\ restored\ area\ [m^2]}{Total\ area\ of\ project\ site\ [m^2]} \cdot 100\ [\%] \tag{215}$$

Figure 97 shows the indicator thresholds used to associate indicator scores to performance classes for B.9.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement. Specifically, greater indicator scores associated with increasing performance classes (i.e. from *Low* to *Excellent*) indicate the corresponding growing efforts for the conservation of both traditional cultivated landscapes and historic green areas within a project.

Figure 97. B.9.2 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
B.9.2 thresholds ($t_{B.9.2}$):	$0 \leq$	$t_{B.9.2,\ Acceptable} \geq 20$	$t_{B.9.2,\ Good} \geq 50$	$t_{B.9.2,\ Excellent} \geq 70$; ≤ 100

Source: JRC.

The B.9.2 score can be increased by promoting the *heritage cultivation*; hence, traditional cultivations that are historically significant to the local community needs to be prioritised to preserve biodiversity and maintain cultural connections to the region heritage. Other measures to improve the B.9.2 score refer to the *protection of heritage trees and plants* within the project area by implementing conservation measures including the identification, assessment, and safeguarding of trees and plants with historical or cultural significance.

4.12.4 Improving preservation of cultural and natural heritage in renovated buildings (B.9.3)

Improving preservation of cultural and natural heritage in renovated buildings (B.9.3) indicator aims to ensure that renovated buildings retain their historical and cultural integrity, contributing to the preservation of cultural and natural heritage in the built environment. The indicator emphasises the importance of restoration practices that respect and enhance the unique heritage value of each building or space (Council of Europe, 2021). This includes preserving the physical features, fabric and contents, minimising unnecessary change and implementing measures that mitigate any unavoidable loss of heritage significance.

The B.9.3 indicator that **only** applies to **not statutory protected cultural and natural heritage** is assessed through the following five metrics:

- *Preserved original/historic structural elements (PSE).*
- *Preserved original/historic openings (PO).*
- *Preserved or enhanced original, historic green spaces (PEGS).*
- *Interaction with immediate surrounding (IIS).*
- *Preserved key features of the building or space (PKF).*

In the general form, the B.9.3 score is evaluated as the weighted average of the scores of the aforementioned five metrics (expressed as percentages), multiplied by 100, to obtain a dimensionless score ranging from 0 to 100, according to Equation (216).

$$B.9.3 = (0.2 \cdot PSE + 0.2 \cdot PO + 0.2 \cdot PEGS + 0.2 \cdot IIS + 0.2 \cdot PKF) \cdot 100 \qquad (216)$$

The B.9.3 indicator pertains to not statutory protected cultural heritage, which include historic buildings that may range from high to low architectural and/or cultural value, thus historic buildings holding low original value are not considered as significant heritage buildings. Therefore, ***PSE*, *PO*,** and ***PKF*** metrics **are applicable or not depending on whether the preservation of original structural elements, openings, and key features of a historic building significantly contribute to maintain the original value of the building or not**. Indeed, in case of historic buildings with low architectural and/or cultural value, these preservation efforts may not be needed, as the intrinsic value of the building is not acknowledged. This means that **PSE**, **PO**, and **PKF** metrics are **not applicable**, and the evaluation of B.9.3 score only relies on *PEGS* and *IIS* metrics according to Equation (217).

$$B.9.3 = \frac{(0.2 \cdot PEGS + 0.2 \cdot IIS)}{0.4} \cdot 100 \quad (217)$$

Preserved original/historic structural elements (PSE) metric, **if applicable**, as within B.9.1 indicator, deals with the conservation of original or historic structural elements of a building, including walls, floors, and roofs. The metric evaluates the extent to which original or historic structural elements are preserved during the renovation process, indicating the degree of conserving the historical integrity and authenticity of the building original structure.

PSE score is calculated as the ratio of the area of preserved original or historic structural elements (i.e. walls, floors, roofs) in square meters (m^2) to the total floor area of the building in square meters (m^2), expressed as a percentage, according to Equation (218).

$$PSE = \frac{Area\ of\ preserved\ structural\ elements\ \ [m^2]}{Total\ floor\ area\ of\ building\ \ [m^2]} \cdot 100\ [\%] \quad (218)$$

Preserved original/historic openings (PO) metric, **if applicable**, as within B.9.1 indicator, examines the preservation or replacement of original/historic openings, such as windows, shutters, and doors, during the renovation. The metric evaluates the extent to which original or historic openings have been maintained properly compared to the total number of openings, indicating the degree of preservation and considering its impact on the building historical character and architectural authenticity.

PO score estimates the ratio of the number of preserved original or historic openings (i.e. windows, shutters, doors) to the total number of openings, expressed as a percentage, according to Equation (219).

$$PO = \frac{Number\ of\ preserved\ openings}{Total\ number\ of\ openings} \cdot 100\ [\%] \quad (219)$$

Preserved or enhanced original, historic urban green spaces (PEGS) metric evaluates how existing green spaces are managed within a project by focusing on whether these spaces are maintained in their original condition or improved to enhance their ecological, social, and aesthetic values, contributing to a healthier and more sustainable environment. The *PEGS* metric provides insights into the effectiveness of projects in maintaining or improving green infrastructure, promoting biodiversity, and enhancing the overall quality of the project environment.

The PEGS score estimates the total area of preserved or enhanced green spaces in a project site, to the total area of the green spaces before the renovation intervention, expressed as a percentage, according to Equation (220).

$$PEGS = \frac{Area\ of\ preserved\ or\ enhanced\ green\ spaces}{Total\ area\ of\ green\ spaces\ before\ the\ intervention} \cdot 100\ [\%] \quad (220)$$

Integration with immediate surrounding (IIS) metric assesses the extent to which a renovated building effectively integrate into its immediate surrounding environment, while safeguarding its cultural and natural heritage. The metric considers factors, such as architectural harmony, landscape integration, and compatibility with neighbouring buildings.

The IIS score is evaluated through two sub-metrics, i.e. (*i*) historical context sensitivity, and (*ii*) conservation planning to which assign a rate based on a scale of points (i.e. 0 to 5), depending on the absence/presence and relevance degree of their specific features within a renovation project, according to the rationale provided in Table 134.

Table 134. Integration with immediate surrounding (IIS) metric score.

Sub-metric	Score (points)
Rate each sub-metric below according to a scale of points (0-5, where 0 corresponds to absence of feature, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of feature) and sum the two scores.	
Historical context sensitivity: evaluate whether and how the renovation respects and responds to the historical context of the surrounding area, including preservation of architectural heritage and cultural significance?	0 to + 5
Conservation planning: evaluate whether and how the renovation aligns with established conservation plans or heritage management strategies for the area, ensuring that interventions are guided by principles of heritage conservation and sustainable development?	0 to + 5
Integration with immediate surroundings (IIS) metric score = Σ sub-metric scores	**0 ≤ IIS ≤ 10**

Source: JRC.

The IIS score, expressed in points, needs to be transformed into a score, expressed as a percentage, ranging from 0 % to 100 %, thus the IIS final score is evaluated as the ratio of the number of points awarded to the maximum possible number of points (i.e. 10), expressed as a percentage, according to Equation (221).

$$IIS = \frac{IIS\ awarded\ number\ of\ points}{IIS\ maximum\ number\ of\ points = 10} \cdot 100\ [\%] \tag{221}$$

The IIS final score indicates different degrees of the perceived integration with the immediate surroundings, according to the following score ranges:

- The IIS score ranging between 0 % and 20 % corresponds to a *very weak* perceived integration with surroundings (i.e. the place exhibits minimal to no discernible integration with its surroundings).
- The IIS score ranging between 21 % and 40 % indicates a *weak* perceived integration with surroundings (i.e. integration is below average, with notable deficiencies in the features outlined within the sub-metrics).
- The IIS score ranging between 41 % and 60 % indicates a *moderate* perceived integration with surroundings (i.e. the place demonstrates moderate integration, meeting the basic features in most aspects outlined within the sub-metrics).
- The IIS score ranging between 61 % and 80 % corresponds to a *strong* perceived integration with surroundings (i.e. integration is above average, with positive performance in most of the features outlined within the sub-metrics; some refinements could further enhance the overall integration).
- The IIS score ranging between 81 % and 100 % refers to a *very strong* integration with surroundings (i.e. the place exhibits effective overall integration in assessed sub-metrics).

Preserved key features of building or space (PKF) metric, **if applicable**, focuses on the maintenance of key historical and architectural features that define the building character and identity. It examines whether the building original purpose, unique architectural elements, and social significance are preserved, ensuring the continuity of its historical narrative. The metric evaluates the preservation of the building historical purpose, and the social value it holds within its community.

The PKF score is evaluated through two sub-metrics: (*i*) social value and (*ii*) historic and cultural relevance to which assign a rate based on a scale of points (i.e. 0 to 5), depending on the absence/presence and relevance degree of their specific features within a project, according to the rationale in Table 135.

Table 135. Preserved key feature of building or space metric score.

Sub-metric	Score (points)
Rate each sub-metric below according to a scale of points (0-5, where 0 corresponds to absence of feature, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of feature) and sum the two scores	
Social value: evaluate the social value that the building or space holds within its community; its role in local history, cultural identity, community memory, or social cohesion.	0 to + 5
Historic and cultural relevance: evaluate the degree to which the building or space remains culturally relevant to the community, and whether it continues to serve its original purpose or has been adapted to meet contemporary needs while retaining its historical identity.	0 to + 5
Preserved key feature of building or space (PKF) metric score = Σ sub-metric scores	**0 ≤ PKF ≤ 10**

Source: JRC.

The PKF score, expressed in points, needs to be transformed into a score, expressed as a percentage, ranging from 0 to 100 %, thus the PKF final score is evaluated as the ratio of the number of points awarded to the maximum possible number of points (i.e. 10), expressed as a percentage, according to Equation (181).

$$PKF = \frac{PKF\ awarded\ number\ of\ points}{PKF\ maximum\ number\ of\ points = 10} \cdot 100\ [\%] \tag{222}$$

The PKF final score indicates different degrees of the perceived preservation of key historical features, according to the following score ranges:

- The PKF score ranging between 0 % and 20 % corresponds to a *very weak* perceived preservation (i.e. minimal preservation efforts observed, with significant loss or degradation of key historical features, limited adherence to preservation guidelines, and minimal recognition of social value within the community).
- The PKF score ranging between 21 % and 40 % is associated to a *weak* perceived preservation (i.e. limited preservation achieved, with some effort made to retain key historical features, but notable alterations or compromises in authenticity and social relevance).
- The PKF score ranging between 41 % and 60 % indicates a *moderate* perceived preservation (i.e. moderate preservation efforts are evident, with a balanced approach to retaining key historical features, while accommodating contemporary needs, and partly recognition of social value within the community is also evident).
- The PKF score ranging between 61 % and 80% corresponds to a *strong* perceived preservation (i.e. substantial preservation is achieved, with significant retention of key historical features, adherence to preservation guidelines, and recognition of social value within the community).
- The PKF score ranging between 81 % and 100% indicates a *very strong* perceived preservation (i.e. exceptional preservation efforts are demonstrated, with attention to retaining and restoring key historical features and widespread recognition of social value within the community).

Figure 98 shows the indicator thresholds used to associate indicator scores to performance classes for B.9.3. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement. Specifically, the four ranges of B.9.3 scores equal to (*i*) 0 ≤ B.9.3 < 20, (*ii*) 20 < B.9.3 ≤ 50, (*iii*) 50 < B.9.3 ≤ 70, and (*iv*) 70 ≤ B.9.3 ≤ 100 are associated with the *Low, Acceptable, Good* and *Excellent* performance class, respectively. The B.9.3 scoring range categorises the overall preservation efforts into different levels based on the improved perseveration of cultural and natural heritage in renovated buildings. A higher score indicates a more comprehensive preservation, while a lower score suggests a lesser degree of preservation.

Figure 98. B.9.3 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.9.3 thresholds ($t_{B.9.3}$):	0 ≤		$t_{B.9.3,\ Acceptable}$ ≥ 20		$t_{B.9.3,\ Good}$ ≥ 50		$t_{B.9.3,\ Excellent}$ ≥ 70		≤ 100

Source: JRC.

B.9.3 score, similarly to B.9.1 score, can be increased by enhancing *preservation efforts* through the identification of additional opportunities to preserve the original architectural elements or historical features within a building and the use of specialised restoration techniques to restore deteriorated components. Other measures to improve B.9.1 score deal with the application of *adaptive reuse methods* to retain original and historic structural elements for new functional purposes to preserve their physical integrity and also add value to the contemporary use of the space. However, the preservation of most of the structural elements could not be feasible in a project. In this case, a *selective restoration*, aimed at prioritising the restoration of key original or historic openings that contribute significantly to the architectural character, should be envisaged. The focus on the most distinctive or culturally significant elements demonstrates targeted and impactful preservation efforts.

4.12.5 Example (B.9)

4.12.5.1 Example (B.9): buildings and spaces with statutory protection

The hypothetical project focuses on the restoration and adaptive reuse of a **statutory protected** historic industrial building within an urban context. The primary goal is to transform the building into a vibrant and functional space while preserving its historical significance. The existing industrial building holds great historical importance, representing an example of a crucial era in the city industrial development. To maintain its historical integrity, efforts are made to preserve original features, such as exposed brickwork, large factory windows, and industrial elements that reflect the history of the building. However, the project also aims to modernise the building to meet current needs, creating a balance between preservation and adaptation. This involves introducing contemporary design elements while respecting the historical character of the structure. Surrounding the building, historic urban green areas and traditionally cultivated landscapes are integrated into the design of the renovation project. Additionally, sustainable land use practices are incorporated, including the use of native plants, water-efficient landscaping, and environmentally conscious maintenance practices. Specifically, the total area of the project site is equal to 5000 m^2, while the total floor area of the building is 1000 m^2 square meters.

The evaluation of B.9 for projects with statutory protection, as in the example, depends on the scores of B.9.1 and B.9.2 indicators (i.e. B.9.3 indicator is omitted).

The **B.9.1 score** is evaluated through the following four metrics: (*i*) preserved patina, (*ii*) preserved original/historic structural elements, (*iii*) preserved original/historic openings, and (*iv*) heritage value.

Preserved patina metric is evaluated based on the assumption that the area of preserved patina represents the intentional conservation of aged surfaces of the external walls of a building. Following a careful cleaning and minimal intervention techniques to retain the original patina, while removing any harmful substances that may compromise its longevity, the area of preserved patina of the analysed building is estimated equal to 650 m^2. The total area of the external walls of the building is equal to 1000 m^2, thus the PP score is evaluated using Equation (209) and results into a value equal to 65 %, according to Equation (223).

$$PP = \frac{650\ m^2}{1000\ m^2} \cdot 100 = 65\ \% \tag{223}$$

Preserved original/historic structural elements (PSE) metric that supports the preservation of the structural elements of a statutory protected historic/cultural building contributing to the structural and visual integrity of cultural heritage, is evaluated by first defining the area of preserved structural elements intentionally retained during the restoration process, which is estimated equal to 750 m^2. The total floor area of the building is 1000 m^2, thus the PSE score is estimated by using Equation (210) and it is found to be equal to 75 %, according to Equation (224).

$$PSE = \frac{750\ m^2}{1000\ m^2} \cdot 100 = 75\ \% \tag{224}$$

Preserved original/historic openings (PO) metric is estimated by first counting the original openings that have been intentionally retained during the restoration process. These include windows, doors, and other architectural openings that were part of the building original design and construction, leading to a number of preserved openings equal to 80 out of the total number of 100 openings present in the analysed building. Hence, the PO score is calculated using Equation (211) and results into a value equal to 80%, according to Equation (225).

$$PO = \frac{80}{100} \cdot 100 = 80\ \% \tag{225}$$

Heritage value (HV) metric is first evaluated in points based on the presence/absence and degree of relevance of the specific features related to the three sub-metrics, i.e. *representativeness, ambient value,* and *aesthetic coherence,* within the heritage site project (Table 133), as reported in the following, leading to the HV score in points equal to 14 (out of 15), as reported in Table 136. Specifically, regarding *representativeness*, the industrial building effectively represents the city industrial history, capturing the essence of the era with attention to detail and historical accuracy. Regarding the *ambient value,* the environmental and aesthetic qualities of the site are commendable, integrating well with the urban context and the adaptive reuse enhances the overall atmosphere. Regarding the *aesthetic coherence*, the architectural features, including original structural elements and openings, are significant and the adaptive reuse combines historical significance with modern functionality.

Table 136. Example of heritage value (HV) evaluation.

Sub-metric	**Score (points)**
Rate each sub-metric below according to a scale of points (0-5, where 0 corresponds to absence of feature, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of features) and sum the three scores.	
Representativeness: evaluate how the heritage site represents a particular period, style, or cultural aspect?	+ 5 (very strong)
Ambient value: evaluate the heritage site environmental and aesthetic qualities, consider its natural surroundings, landscape, and overall atmosphere.	+ 4 (strong)
Aesthetic coherence: evaluate the architectural significance, innovation, and craftsmanship of the buildings within the heritage site.	+ 5 (very strong)
Heritage value (HV) metric score = Σ sub-metric scores	**HV = 14**

Source: JRC.

The HV score, expressed in points, is transformed into the HV final score by using Equation (181), thus estimating equal to 93.3 %, as provided through Equation (199). According to the significance of the five score ranges corresponding to different degrees of the perceived heritage value (Section 4.12.2), the HV score indicates a very strong perceived heritage value. It effectively represents the intended period, high environmental and aesthetic qualities, and the architectural features are significant. The adaptive reuse balances historical integrity with modern functionality, contributing positively to the urban context.

$$HVA = \frac{14}{15} \cdot 100 = 93.3\ \% \qquad (226)$$

Having evaluated the score of each metric, B.9.1 score is calculated according to Equation (208), resulting into a value equal to 78.3, corresponding to the indicative *Excellent* performance class (Figure 96), as reported in Table 137. The indicator score indicates that the project holds an excellent preservation due to a comprehensive approach to the restoration and reuse of the historic industrial building, highlighting the successful balance between historic integrity and contemporary functionality, mainly emphasised by the efforts to preserve the patina the original structural elements and the historic openings of the building.

Table 137. Example of B.9.1 evaluation

Metric	**PP**	**PSE**	**PO**	**HV**
Metric score	65 %	75 %	80 %	93.3 %
B.9.1 score	= (0.25 · 65 % + 0.25 · 75 % + 0.25 · 80 % + 0.25 · 93.3%) · 100 = 78.3			
B.9.1 performance class	(Excellent)[1]			

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

The **B.9.2 score** is evaluated through the following two metrics: (*i*) traditional cultivated landscape preservation and restoration, and (*ii)* preserved or recovered original, historic green areas.

Traditional cultivated landscape preservation and restoration (TLPR) metric is evaluated based on the following two sub-metrics: (*i*) the preserved area of traditional cultivated landscape within the project is equal to 2000 m^2 and (*ii*) the area of the project site is 5000 m^2. Hence, the TLPR score is calculated using Equation (214), thus resulting into a value equal to 40 %, according to Equation (227).

$$TLPR = \frac{2000\ m^2}{5000\ m^2} \cdot 100 = 40\ \% \tag{227}$$

Preserved or recovered original, historic green spaces (PRGS) metric is evaluated based on the following sub-metrics: (*i*) the area of recovered original, historic green spaces within the project is equal to 2500 m^2 and (*ii*) the area of the project site is 5000m^2. Hence, TLPR score is calculated using Equation (215) and results into a value equal to 40 %, as reported in Equation (228).

$$PRGS = \frac{2500\ m^2}{5000\ m^2} \cdot 100 = 50\ \% \tag{228}$$

Having evaluated the score of each metric, B.9.2 score is calculated according to Equation (213), resulting into a value equal to 45, corresponding to the indicative *Acceptable* performance class (according to Figure 97), as reported in Table 138. The project demonstrates a commitment to preserving both traditionally cultivated landscapes and historic green areas. Although B.9.2 score can be improved to attain a better performance, the project lays the foundation for heritage conservation and urban green space revitalisation, contributing positively to the historical and ecological fabric of the environment.

Table 138. Example of B.9.2 evaluation

Metric	**TLPR**	**PRGA**
Metric score	40 %	50 %
B.9.2 score	= (0.5 · 40 % + 0.5 · 50 %) · 100 = 45	
B.9.2 performance class	(Acceptable)[1]	

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

Having evaluated the two indicators, the **B.9 score** is estimated using Equation (206) and it is found to be equal to 65, which corresponds to the *Good* performance class (according to Figure 95), as reported in Table 139. This score indicates good conservation efforts of the project regarding building preservation, as well as historical natural heritage preservation. In terms of building preservation, the project demonstrates a strong commitment to maintaining the historical integrity of the former industrial building. The adaptive reuse of the building ensures its continued relevance and functionality while respecting its historical character. Regarding historical natural heritage preservation, the project excels in integrating historic green spaces and traditionally cultivated landscapes into the surrounding area. These elements not only enhance the aesthetic appeal of the project but also contribute to the preservation of the natural heritage of the site. Overall, the project efforts in both building and natural heritage preservation contribute to a positive score, indicating a successful balance between historical conservation and contemporary adaptation within the urban context.

Table 139. Example of B.9 (project statutory protected) evaluation.

Indicator	**B.9.1**	**B.9.2**
Indicator score	78.3	45
B.9 score	= 0.6 · 78.3 + 0.4 · 45 = 65	
B.9 performance class	Good	
B.9 performance class score ($PCS_{B.9}$)	70	

Source: JRC.

4.12.5.2 Example (B.9): buildings without statutory protection but with historical significance

The hypothetical project focuses on the restoration of a building within a historic urban context. The building is part of a planned city block that dates back to the early 20th century and is integral to the wider city centre. Although certain parts of the city block hold significant historical value, the building itself is **not statutory protected**. However, the tenants have decided to renovate the building, aiming to preserve its original elements and appearance as much as possible, acknowledging its intrinsic value to the urban fabric. Situated within the city block, the building has a total floor area of 2000 m^2.

The evaluation of B.9 for cultural heritage projects without statutory protection depends on B.9.3 indicator (i.e. B.9.1 and B.9.2 are omitted), which is estimated through the following five metrics: (*i*) preserved original/historic structural elements, (*ii*) preserved original/historic openings, (*iii*) preserved or enhanced green areas, (*iv*) interaction with immediate surrounding, and (*v*) preserved key features of the building or space. The building has a high cultural value, although it is not statutory protected, so the *preserved original/historic structural elements*, the *preserved original/historic openings,* and the *preserved key features* metrics are applicable for the B.9 evaluation.

Preserved original/historic structural elements (PSE) metric is evaluated based on the assumption that an area of original structural elements, including walls and ceilings, equal to 800 m^2 have been preserved through renovation efforts. Hence, the PSE score is evaluated using Equation (218) and results into a value equal to 40 %, according to Equation (229).

$$PSE = \frac{800\ m^2}{2000\ m^2} \cdot 100 = 40\ \% \qquad (229)$$

Preserved original/historic openings (PO) metric is evaluated based on the following sub-metrics: the building accounts for 50 openings, comprising windows and doors, and an amount of 35 out of the total number of 50 openings have been painstakingly preserved. Hence, *PO* score is estimated according to Equation (219) and results into a value equal to 70 %, as reported in Equation (230).

$$PO = \frac{35}{50} \cdot 100 = 70\ \% \qquad (230)$$

Preserved or enhanced original/historic green spaces (PEGS) metric is evaluated based on the assumption that green spaces, accounting for a total area equal to 500 m^2, within the vicinity of the renovated building were carefully considered during the renovation. Efforts led to the preservation and enhancement of an area of these green spaces equal to 300 m^2. Hence, the PEGS score is estimated using Equation (220) resulting equal to 60 %, as reported in Equation (231).

$$PEGS = \frac{300\ m^2}{500\ m^2} \cdot 100 = 60\ \% \qquad (231)$$

Integration with the immediate surroundings (IIS) metric evaluates how well a renovated building integrates with its immediate environment while preserving its cultural and natural heritage. The IIS metric is first evaluated in points (Table 134) based on the presence/absence and degree of relevance of the specific features related to the two sub-metrics, i.e. historical context sensitivity, and conservation planning, as reported in the following, leading to the IIS score in points equal to 9 (out of 10), as reported in Table 140. Specifically, the *historical context sensitivity* was of great importance during renovation, as reflected in the approach to the renovation by ensuring that the architectural elements and design choices were in thematic consistency with the historical fabric of the surrounding environment. The sensitivity to historical context ensured that the renovation enhanced the relationship of the building with its historical setting, rather than detracting from it. The *conservation planning* efforts align into the established strategies by adhering to conservation guidelines and incorporating sustainable practices. By following conservation guidelines, the renovation also contributed to long-term sustainability and minimised the environmental impact.

Table 140. Example of integration with immediate surroundings (IIS) evaluation.

Sub-metric	**Score (points)**
Rate each sub-metric below according to a scale of points (0-5, where 0 corresponds to absence of feature, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of feature) and sum the two scores.	
Historical context sensitivity: evaluate whether and how the renovation respects and responds to the historical context of the surrounding area, including preservation of architectural heritage and cultural significance?	+ 4 (strong)
Conservation planning: evaluate whether and how the renovation aligns with established conservation plans or heritage management strategies for the area, ensuring that interventions are guided by principles of heritage conservation and sustainable development?	+ 5 (very strong)
Integration with immediate surroundings (IIS) metric score = Σ sub-metric scores	**IIS = 9**

Source: JRC.

The IIS score, expressed in points, is transformed into the IIS final score by using Equation (221), thus estimating equal to 90 %, as provided through Equation (232). According to the five score ranges corresponding to different degrees of the perceived integration with the immediate surroundings (Section 4.12.2), the IIS score indicates a very strong perceived integration with surroundings.

$$IIS = \frac{9}{10} \cdot 100 = 90\ \% \tag{232}$$

Preserved key features of building or space (PKF) metric is first evaluated in points (Table 135) based on the presence/absence and degree of relevance of the specific features related to two sub-metrics, i.e. social value and historic and cultural relevance, as reported in the following, leading to the PKF score in points equal to 8 (out of 10), as reported in Table 141. Regarding the s*ocial value*, the project reveals a strong social value within the community, through its connection with local history and cultural identity for which the building remains a significant asset. Regarding the ***historical and cultural significance***, the renovation project ensured that the historical and cultural significance was unmodified and carefully preserved throughout the renovation process.

Table 141. Example of preserved key feature of building or space (PKF) evaluation.

Sub-metric	**Score (points)**
Rate each sub-metric below according to a scale of points (0-5, where 0 corresponds to absence of feature, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of feature) and sum the two scores.	
Social value: evaluate the social value that the building or space holds within its community; its role in local history, cultural identity, community memory, or social cohesion.	+ 4 (strong)
Historic and cultural relevance: evaluate the degree to which the building or space remains culturally relevant to the community, consider whether it continues to serve its original purpose or has been adapted to meet contemporary needs while retaining its historical identity.	+ 4 (strong)
Preserved key feature of building or space (PKF) metric score = Σ sub-metric scores	**PKF = 8**

Source: JRC.

The PKF score, expressed in points, is transformed into the PKF final score by using Equation (222), thus estimating equal to 80 %, as provided through Equation (233). According to the five score ranges corresponding to different degrees of the perceived integration with the immediate surroundings (Section 4.12.4), the PKF score indicates a very strong perceived preservation of key historical features.

$$PKF = \frac{8}{10} \cdot 100 = 80\ \% \tag{233}$$

Having evaluated the score for each metric, the **B.9.3 score** is estimated according to Equation (216). The B.9.3 score corresponds to the B.9 score for non-statutory protected buildings (Equation (207)), which is estimated equal to 68 %, thus resulting into a *Good* performance class (Figure 95), as reported in Table 142. The B.9 score indicates that the historic building renovation project exemplifies an effort in preserving the cultural and natural heritage, while bringing vitality into the urban fabric by integrating modern elements to enhance its functionality and appeal.

Table 142. Example of B.9.3 and B.9 (non-statutory protection) evaluation.

Indicator	B.9.3
Indicator score	= (0.2 · 40 % + 0.2 · 70 % + 0.2 · 60 % + 0.2 · 90 % + 0.2 · 80 %) · 100 = 68
Indicator performance class	(Good)[1]
B.9 score	= 1 · 68 = 68
B.9 performance class	Good
B.9 performance class score ($PCS_{B.10}$)	70

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

4.13 Maintaining *genius loci* and improving sense of belonging (B.10)

4.13.1 Description and assessment

Maintaining genius loci and improving the sense of belonging (B.10) KPI aims to preserve the unique character and essence of a place, commonly referred to as *genius loci*, while nurturing an emotional bond and attachment among community members. *Genius loci* is connected with the concept of sense of place, which relates to the authenticity (a clear definition of authenticity is provided in the 'List of abbreviations and definitions' section) of the built and non-built environment, characterised by its social fabric and all associated interaction, as well as its natural and physical identity (European Commission, 2021b). This encompasses the preservation of historical and cultural elements and the promotion of sustainable practices that uphold local identity (COM, 2018). Achievement is assessed through heightened appreciation for the distinct identity of the locale inhabitants. B.10 emphasises the importance of the sense of belonging within the community and the distinctiveness of the places, serving as a tool to promote community cohesion and resilience, as well as recognising and preserving the unique spirit of a place, not only by replicating "ancient" models, but also highlighting the identity of the place and reinterpreting it in a contemporary manner.

B.10 is evaluated through one main indicator, as follows:

— *Sense of place harmony (B.10.1)*, which aims to foster or recognise and preserve the unique spirit of a place, encompassing its characteristic features and emotional identity.

B.10 score, ranging from 0 to 100, is calculated according to the Equation (234).

$$B.10 = w_{B.10.1} \cdot B.10.1 / w_{B.10.1} = 1 \cdot B.10.1 \quad (234)$$

Figure 99 provides the B.10 KPI performance classes and thresholds adopted in the self-assessment method. Hence, the four ranges of B.10 score, equal to 0 ≤ B.10 < 20, 20 ≤ B.10 < 50, 50 ≤ B.10 < 80, and 80 ≤ B.10 ≤ 100, correspond to *Low*, Acceptable, *Good*, and *Excellent* performance class, respectively. It is highly recommended that B.10 attains as a minimum the Acceptable performance class. This recommendation points out the importance of preserving the genius loci and enhancing the sense of belonging within communities. Increased appreciation of the distinct identity of the inhabitants of a place serves as a measure for evaluating what has been achieved.

Figure 99. B.10 performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.10 thresholds ($t_{B.10}$):	0 ≤		$t_{B.10, Acceptable}$ ≥ 20		$t_{B.10, Good}$ ≥ 50		$t_{B.10, Excellent}$ ≥ 70		≤ 100

Source: JRC.

The B.10 KPI and its corresponding indicator can be applied to projects at **building**, **neighbourhood** and **urban** scale, considering both **newbuild** and **renovation** project types, **exclusively with non-residential** use, thus excluding residential buildings, as the KPI evaluates the project alignment with the community's values. Specifically, at building scale, the B.10 KPI and the B.10.1 indicator can be applied to new buildings and the redevelopment of single buildings, ensuring that the sense of place harmony is maintained within the project environment. At neighbourhood and urban scale, the B.10 KPI and the B.10.1 indicator can be applied to large parts of an urban area or a village/city, referring to geographic areas that constitute a distinct neighbourhood or larger portions of a city. The B.10 KPI and the B.10.1 indicator can be applied to historical environments, natural landscapes, and heritage sites where maintaining a sense of place harmony is crucial for upholding the cultural identity and emotional resonance of the area. At building and neighbourhood scales, the features of the cultural landscape should be viewed within the context of the broader landscape of which they are an integral part.

4.13.2 Sense of place harmony (B.10.1)

Each "place" possesses distinct character and attributes that contribute to its unique presence or *genius loci* (Norberg-Schulz, 1980). The *genius loci* that differentiates each place is defined by how a culture attributes diverse textures, forms, and meanings to its environment (Karaman, 2001). Thus, the place reflects how individuals or groups have transformed their living spaces, with their responses to environmental limitations or potentials etched into the landscape (a clear definition of landscape is provided in the 'List of abbreviations and definitions' section). Sense of belonging is intended as the capability to adapt to the qualities of the place, either as inherited from previous generations and civilizations, or as jointly created for the future. It is the willingness to contribute to the preservation and enhancement of existing, and mostly objective qualities, but also behave respectfully towards other individuals, past, present and future, of the social groups inhabiting the place, being it either a community on the traditional form or a new community, today defined as heritage or aesthetic.

The *Sense of place harmony (B.10.1)* indicator assesses the unique cultural identity, emotional resonance, and sense of place within a designated geographic area, emphasising these elements imbued with deeper significance for its inhabitants. It examines whether spatial solutions within a project consider the needs of individuals, communities, spaces and places, of values and resources (European Commission, 2021b).

The B.10.1 indicator is assessed through the following two metrics:

— *Rareness of landscape/heritage site types (RS).*

— *Sense of attachment (SA).*

B.10.1 score, ranging from 0 to 100, is calculated as the weighted average of the aforementioned two metric scores, according to Equation (235).

$$B.10.1 = (0.5 \cdot RS + 0.5 \cdot SA) \cdot 100 \qquad (235)$$

Rareness of landscape/heritage site types (RS) metric assesses and quantifies the uniqueness and scarcity of specific landscape or site types within a defined geographic area. The metric acknowledges that certain landscapes or sites possess distinctive features, ecological elements, or cultural characteristics that contribute to their rarity. A landscape or site can be recognised and determined as a cultural landscape, based on the interaction of humankind and the natural environment, according to one of the following three categories (UNESCO, 2008):

1. The *'clearly defined landscape designed and created intentionally by man'* includes garden and parkland landscapes, which are constructed for aesthetic reasons, often (but not always) associated with religious or other monumental buildings and ensembles.
2. The *'organically evolved landscape'* has evidence of the human interaction with the natural environment, but it is changed and developed over time. Interaction between different elements (i.e. social, economic, administrative, and/or religious imperative) and the land is evident.
3. The *'associative cultural landscape'*, in which religious, artistic or cultural features are associated with the environmental elements. However, the evidence of historical human use of the site may be missing.

The three categories of landscapes or sites can be inscribed to a heritage list referring to a specific legal framework at local, national or international level, thus achieving official protection and resulting into protected landscape (i.e. statutory protected area) or heritage site; alternatively, they can be protected by a spatial plan at local or regional level.

The RS metric evaluates whether a project satisfies the aforementioned features to be recognised as a cultural landscape or heritage site. The rationale for the evaluation of RS score, which can be equal to ten different fixed values, expressed as percentages, is presented in Table 143.

Table 143. Rareness of landscape/heritage site types (RS) metric score.

Sub-metric	Score
Select single value below.	
Landscape or site not recognised as a cultural or natural landscape	0 %
Landscape having features of one out of the three categories of cultural landscape: 'clearly defined landscape', **or** 'organically evolved landscape', **or** 'associative cultural landscape'	20 %
Landscape having features of two out of the three categories of cultural landscape	30 %
Landscape having features of all the three categories of cultural landscape: 'clearly defined landscape', **and** 'organically evolved landscape', **and** 'associative cultural landscape'	40 %
Landscape protected by a spatial plan at local level	50 %
Landscape protected by a spatial plan at regional level	60 %
Landscape or heritage site protected at local level	70 %
Landscape or heritage site protected at regional level	80 %
Landscape or heritage site protected at national level	90 %
Landscape or heritage site protected at international level	100 %
RS metric score = Selected sub-metric score	**RS = one of the fixed value above**

Source: JRC.

Sense of attachment (SA) metric evaluates the extent to which individuals experience a sense of attachment and emotional connection to a building, landscape or site. The metric considers the emotional bonds people create with the environment, reflecting on how they perceive and interact with a building, landscape or heritage site. The evaluation of sense of attachment aims to ascertain the degree to which community's sense of identity and belonging to a building or site are upheld, thus a project should ensure the preservation of local unique character and identity, as well as the consistency of its use with the level of carrying capacity of the area that can be sustainably supported without causing significant negative impacts on the quality of life.

SA score is evaluated through two sub-metrics: (*i*) community's sense of identity and belonging, and (*ii*) quality and well-being of the inhabitants, to which assign a score based on a scale of points (i.e. 0 to 5), according to the rationale in Table 144.

Table 144. Sense of attachment (SA) metric score.

Sub-metric	Score (points)
Rate each sub-metric below according to a scale of points (0-5, where 0 corresponds to absence of feature, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of features) and sum the two scores	
Community's sense of identity and belonging: evaluate the extent to which the project takes into account the context and unique local character that is characterised by its distinctiveness, authenticity and identity, considering both tangible (e.g. architectural features, landscaping and surroundings, functional features, etc.) and intangible aspects (e.g. cultural practices, social interactions, etc.), thus fostering a strong sense of connection and contributing to a sense of belonging.	0 to + 5
Quality and well-being of the inhabitants: evaluate the extent to which the use of building or space is consistent with the carrying capacity of the area and ensures the preservation or improvement of the spatial quality and well-being of the inhabitants of the area.	0 to + 5
Sense of attachment (SA) metric score = Σ sub-metric scores	**0 ≤ SA ≤ 10**

Source: JRC.

The SA score, expressed in points, needs to be transformed into a score, expressed as a percentage, ranging from 0 % to 100 %, thus the final SA score is evaluated as the ratio of the number of points awarded to the maximum possible number of points (i.e. 10), multiplied by 100, according to Equation (236).

$$SA = \frac{SA\ awarded\ number\ of\ points}{SA\ maximum\ number\ of\ points = 10} \cdot 100\ [\%] \quad (236)$$

The SA score indicates different degrees of the project contribution to the sense of attachment, according to the following score ranges:

— The score ranging between 0 % and 20 % corresponds to a *very weak* perceived contribution of the project to the sense of attachment (the impact is insufficient, and there is little to no positive influence).

— The score ranging between 21 % and 40 % corresponds to a *weak* perceived contribution to the sense of attachment (the self-assessed project has a limited contribution, and improvements are needed to strengthen community ties).

— The score ranging between 41 % and 60 % indicates a *moderate* perceived contribution to sense of attachment (the assessed project has a satisfactory and balanced contribution).

— The score ranging between 61 % and 80 % corresponds to a *strong* perceived contribution to the sense of attachment (the assessed project has a substantial and noticeable contribution to the sense of attachment),

— The score ranging between 81 % and 100 % is associated with a *very strong* perceived contribution to the sense of attachment (the assessed project has transformative contribution to the community's sense of attachment, deeply shaping community identity and creating a strong sense of belonging among community members).

Figure 100 shows the indicator thresholds used to associate indicator scores to performance classes for B.10.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement. As expected, the thresholds for B.10.1 correspond to the ones defined for B.10. Specifically, a high B.10.1 score, corresponding to an indicative *Good* or *Excellent* performance class, suggests that the project is adequately preserving the unique cultural identity, emotional resonance, and sense of place within the designated geographic area, emphasising elements with deeper significance for its inhabitants. It implies a higher level of harmony with the cultural and natural heritage of the region.

Figure 100. B.10.1 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
B.10.1 thresholds ($t_{B.10.1}$):	$0 \leq$	$t_{B.10.1,\ Acceptable} \geq 20$	$t_{B.10.1,\ Good} \geq 50$	$t_{B.10.1,\ Excellent} \geq 70$ ≤ 100

Source: JRC.

The B.10.1 score can be increased by enhancing the preservation of original urban/cultural environment through the prioritisation of the alignment with the original appearance of the urban or cultural environment in new or renovated elements. This can achieved by using photographic analysis, maps, and drawings to guide the design process, and ensuring a high degree of preservation of the intrinsic nature of the area. Other measures to improve B.10.1 score concern the increase of the community involvement. Specifically, the local community should be involved during the project planning and decision-making phase to seek their input, opinions and preferences ensuring the project alignment with the values of the community. Furthermore, attention needs to be drawn on cultural sensitivity and inclusivity. Specifically, it is essential to invest time to understand the community's unique history, traditions and cultural dynamics in order to tailor the project to reflect and respect these cultural elements, thus fostering a sense of cultural identity and inclusivity.

4.13.3 Example (B.10)

The hypothetical project refers to the redevelopment of an urban area with historical significance. The project aims to revitalise the existing urban area while preserving its cultural heritage and meeting the evolving needs of the community. To achieve this goal, the project emphasises substantial revitalisation efforts by involving engaging community members, local businesses, and other stakeholders in the planning and decision-making processes. By involving the community, the project ensures that it aligns with their values and aspirations. One of the key aspects of the redevelopment is the incorporation of public art installations which serve as focal points within the urban area, contributing to its visual appeal. Public art installations convey stories and narratives that resonate with the community, further strengthening the cultural identity of the area. Overall, the project seeks to breathe new life into the urban area, while honouring its past and meeting the needs of the present community. Through collaboration and thoughtful design, it aims to create a vibrant and inclusive space that celebrates the cultural heritage of the area.

The evaluation of B.10 depends on the **score of B.10.1** indicator, which is estimated through the rareness of landscape/site types and sense of attachment metrics.

Rareness of landscape/site types metric is evaluated by comparing the example neighbourhood scale project with the features to recognise a landscape as cultural, according to the sub-metrics in Table 143. Based on the comparison, the project area is recognised as a cultural landscape with features of the 'clearly defined landscape' and the 'associative cultural landscape' categories of cultural landscape, thus RS score is estimated equal to 30, as the project area has features of two out of the three categories of cultural landscape (based on the assessment of the project evaluator).

Sense of attachment metric is first evaluated in points based on the presence/absence and degree of relevance of the specific features related to the two sub-metrics, i.e. *community's sense of identity and belonging*, and *quality and well-being of the inhabitants* (Table 144), as reported in the following, leading to the SA score in points equal to 8 (out of 10), as reported in Table 145. Specifically, regarding the *community's sense of identity and belonging*, the project approach, incorporating historical preservation, cultural integration, and community engagement, suggests a *moderate* positive impact on community's identity and belonging, thus attaining a score of 3 points. Regarding the *quality and well-being of the inhabitants,* the project acknowledges and preserves the historical significance of the urban area and this contextual understanding leads to a very strong positive influence on community attachment, thus earning a score of 5 points.

Table 145. Example of sense of attachment evaluation.

Sub-metric	**Score (in points)**
Rate each sub-metric below according to a scale of points (i.e. 0-5, where 0 corresponds to absence of features, 1 to very weak, 2 to weak, 3 to moderate, 4 to strong, and 5 to very strong presence of features) and sum the two scores.	
Community's sense of identity and belonging: evaluate the extent to which the project takes into account the context and unique local character that is characterised by its distinctiveness, authenticity and identity, considering both tangible (e.g. architectural features, landscaping and surroundings, functional features etc.) and intangible aspects (e.g. cultural practices, social interactions etc.), thus fostering a strong sense of connection and contributing to a sense of belonging.	+ 3 (moderate)
Quality and well-being of the inhabitants: evaluate the extent to which the use of building or space is consistent with the carrying capacity of the area and ensures the preservation or improvement of the spatial quality and well-being of the inhabitants of the area.	+ 5 (very strong)
Sense of attachment (SA) metric score = Σ sub-metric scores	**SA = 8**

Source: JRC.

The SA score, expressed in points, is transformed into the SA final score by using Equation (208), thus resulting equal to 80, as reported in Equation (237). According to the significance of the five score ranges corresponding to different degrees of the perceived sense of attachment (Section 4.13.2), the SA score indicates a strong perceived contribution to the sense of attachment.

$$SA = \frac{8}{10} \cdot 100 = 80 \qquad (237)$$

Having evaluated the score for each metric, B.10.1 score is estimated according to Equation (235), which corresponds to B.10 score (Equation (234)), thus resulting into a *Good* performance class (Figure 99), as reported in Table 146. The result is showcasing a strong commitment to preserving the cultural heritage of the area while fostering a sense of community belonging.

Table 146. Example of B.10.1 and B.10 evaluation.

Indicator	**B.10.1**
Indicator score	= 0.5 · 30 + 0.5 · 80 = 55
Indicator performance class	(Good)[1]
B.10 score	= 1 · 55 = 55
B.10 performance class	Good
B.10 performance class score ($PCS_{B.10}$)	70

[1] Transformation of the indicator score to an indicator performance class is indicative and not required by the self-assessment method to estimate KPI and dimension scores and performance classes.

Source: JRC.

4.14 Understanding aesthetic perception of buildings and spaces through comparison to actual ‘styles’ and tendencies in art and architecture (B.11)

4.14.1 Description and assessment

Understanding aesthetic perception of buildings and spaces through comparison to actual ‘styles’ and tendencies in art and architecture (B.11) KPI is assessed through the following indicator:

— *Cognitive experience (B.11.1)*, which relates to the semantic aspects of aesthetic experience.

B.11 score, ranging from 0 to 100, is evaluated according to Equation (238):

$$B.11 = w_{B.11.1} \cdot B.11.1 / w_{B.11.1} = 1 \cdot B.11.1 \quad (238)$$

Figure 101 provides B.11 performance classes and thresholds adopted in the self-assessment method. Hence, the four range of B.11 scores, equal to $0 \leq B.11 < 20$, $20 \leq B.11 < 50$, $50 \leq B.11 < 80$, and $80 \leq B.11 \leq 100$, correspond to *Low*, Acceptable, *Good*, and *Excellent* performance class, respectively. It is highly recommended that B.11 attains as minimum the Acceptable performance class. This recommendation points out the project level of semantic and symbolic advancement in the context of contemporary architectural ‘styles’ and illustrate the project degree of commitment to promoting solutions specific to biophilic design.

Figure 101. B.11 performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
B.11 thresholds ($t_{B.11}$):	$0 \leq$		$t_{B.11,\ Acceptable} \geq 20$		$t_{B.11,\ Good} \geq 50$		$t_{B.11,\ Excellent} \geq 80$		≤ 100

Source: JRC.

B.11 KPI and its corresponding indicator are designed to be implemented **exclusively at building scale**, including **only newbuild** projects with both **residential** and **non-residential** use. Furthermore, it is essential to note that the KPI and its corresponding indicator are **not applicable to cultural heritage buildings**.

4.14.2 Cognitive experience (B.11.1)

The *cognitive experience (B.11.1)* indicator refers to the cognitive (semantic), symbolic, and imaginative aspects of aesthetic experience. Since architecture is largely considered as a product of society and its perceptions and interpretations are variable over time, models developed within contemporary trends and 'styles' are assumed as the point of reference for newly designed buildings. The term 'style' is usually used to refer to a set of features, elements and principles that define the architectural practice in a given historical period. 'Style' is a way of categorising and identifying buildings based on their common linguistic form and cultural context. It is a reflection of the beliefs, values and artistic preferences of societies at a given time and place. However, contemporary architecture is formally diverse and has no defined 'style'. It is mainly dominated by contemporary modernism, which is a multi-faceted and pluralistic movement. The common denominator of this trend is a critical view of the intellectual basis of architecture. In addition to contemporary modernism, other crucial trends in present-day architecture are deconstructivism, eco-architecture, and different varieties of regionalism. In this context, the scientific research on the positive impact of nature on human wellbeing has confirmed the relevance gained in recent years by the concept of eco-architecture and the 'trend' of biophilic design (Kellert and Wilson, 1995), also resulting in line with the NEB philosophy. Biophilic design aims to build a satisfactory relationship between humans and the natural environment based on their evolutionary needs. Elements of biophilic design can be applied to architectural design regardless of the 'style', scale, and location of buildings.

The B.11.1 indicator assesses the issues of 'style' and 'tendency' through the following two metrics:

— *Actual Styles (AS).*

— *Design Tendency (DTen).*

B.11.1 score, ranging from 0 to 100, is evaluated as the weighted average of the two aforementioned metric scores, according to Equation (239).

$$B.11.1 = 0.4 \cdot AS + 0.6 \cdot DTen \quad (239)$$

Actual style (AS) metric establishes the level of aesthetic perception of a new building project with reference to the model features of the 'style' used, among the following four contemporary basic 'styles':

- *Eco-architecture* is part of the sustainable design trend, manifested by a particular concern for the environment and the economic use of resources and materials throughout the building life cycle. The main objective of the eco-architecture design is to reduce the impact that construction sector produces on human health and its surroundings.
- *Contemporary modernism* refers to the repertoire of spatial forms and detailing of inter-war modernism, but does not refer to either the socio-political or urban ideas of the original modernism. Contemporary modernism stood in opposition to the eclecticism of postmodernism, seeking in geometric simplicity a suitable means of expression for the present. References to the philosophy of Piet Mondrian and Kazimir Malevich can be found in contemporary modernism. Mondrian was a pioneer of abstractionism, and his art was utopian and concerned with the search for a universal aesthetic. Abstractionism uses lines, shapes and colours to create compositions that can exist independently of real visual references. Mondrian's abstractionism consisted of creating rectangular grids and filling them with basic colours, and in its ideological layer it referred to classicism, Platonic values and Euclidean geometry. Malevich was the founder of suprematism, an artistic trend in which geometric forms, especially the square and the circle, formed the basis of artistic expression. Suprematism stood in opposition to constructivism and embodied a deeply anti-materialist and anti-utilitarian philosophy. The simplicity of the forms signified a new beginning. The so-called 'new rigorism', in which the form of a building is determined by its structure and functional layout, belongs to the contemporary modernist direction.
- *Deconstructivism* opposes the rationality of modernism and is characterised by the idea of fragmentation, and curvilinear shapes that serve to disrupt volumes and structures. It is inspired by the theory of chaos (specifically, the theory of catastrophes), the fractal geometry, the phenomenology and the concept of falsification. In the conceptual stage of design, the basic forms, shapes, surfaces, lines or ideas are 'destroyed' to open new creative opportunities for their deconstruction. Deconstructivist buildings freely play with forms and elements taken from different traditions, which change their previous meaning and function in new arrangements. Visually deconstruction often refers to catastrophes, such as bifurcation, folding, squeezing, tearing, cutting, breaking, etc. At the ideological level, the deconstructivism style is an attempt to translate the philosophy of Jacques Derrida into the language of building design (Wigley, 1997). However, critics of deconstructivism consider this style as a formal exercise without social meaning and deconstructed building forms are perceived as aggressive to the human senses (Curl, 2006).
- *Regionalism* is a trend in architectural design in which patterns are drawn from traditions linked to geographical and cultural contexts. Buildings are adapted to local conditions and climate, as well as use local materials. However, this trend does not rely on a process of copying, but of referring to the local building tradition, drawing lessons from observations while applying concepts, models and theories based on Environment-Behaviour Studies (Dahl, 2010). On an ideological level, regionalism uses a traditional language of forms and stands in opposition to uniformity. On the theoretical level, the style is underpinned by the theory of critical regionalism (Frampton, 1983), theories of cultural heritage preservation, as well as inspirations drawn from psychology (e.g. theories of physical and psychical well-being). Regionalism is not the equivalent of vernacular architecture, which is not designed by architects but constructed by local craftsmen using traditional materials and resources from the area in which a building is located (Vellinga, 2006).

To evaluate the AS metric, the assessor must first identify which 'style' is mostly used in a new building project to be self-assessed (Table 147), considering that each 'style' is characterised by specific basic features concerning different categories (i.e. shape, colour, texture and material, composition, spatial organisation, technological and structural solutions, and semantic and theoretical framework) to be compared with the design solutions adopted in the new building project to be self-assessed.

Table 147. Identification of the ‘style’ used in the project.

Style	Selection
Select the most used ‘style’ in the project (single selection allowed)	
Eco-architecture	
Contemporary modernism	
Deconstructivism	
Regionalism	

Source: JRC.

The *actual style (AS)* metric evaluates the extent to which the basic features of each of the aforementioned four contemporary styles are applied to a new building project, after identifying the style (among the four) mostly used in the new building project to be self-assessed (Table 147). Table 148 to Table 151 provide the rationale for the evaluation of the AS score related to each of the four styles. AS score can be equal to four different fixed values (i.e. 0, 40, 70, 100) indicative of four performance classes (i.e. low, acceptable, good, and excellent) of the attained aesthetic perception of a building project, noting though that metric performance classes are not used in the current version of the self-assessment method. Specifically, the acceptable and good performance indicate an increasing use of the features of a given ‘style’ in the building project. The excellent performance demonstrates the assessment of an in-depth, multi-faceted understanding and application of a given 'style', providing the observer of the architecture with a chance for a satisfying his/her cognitive experience.

Table 148. Actual style (AS) metric score - Eco-architecture.

Sub-metric	Score
*If the **eco-architecture** style has been identified as the most used style of the project, select single value below.*	
The new building project does not demonstrate any features of the eco-architecture style.	0 (Low)
The new building project is characterised by the following basic features of the eco-architecture style: — **Shape** - Bio-based forms, shapes or patterns revealing reference to natural forms, shapes, organisms. — **Colour** - Colours of natural materials (e.g. clay, earth, limestone, granite, wood). — **Textures and materials** - Use of natural building and finishing materials. — **Spatial organisation** - Arrangement of spaces are determined by light and weather conditions.	40 (Acceptable)
The new building project is characterised by the following basic features of the eco-architecture style: — **Shapes** - Shapes, patterns and composition show references to self-generating biological systems. — **Colour** - Colour palette based on bright colours with gradation of their shades, and colours of natural materials. — **Textures and materials** Use of natural building and finishing materials. Wood, stone, bamboo, recycled materials, re-used materials and elements of buildings exposed in visually appearing way, often rammed earth, hempcrete, compressed earthen blocks, adobe and ‘super-adobe’. Use of chiaroscuro to create building forms. — **Composition** - Shapes and patterns are arranged into integral whole similar to a biological organism (e.g. plant) or non-organic natural structure (e.g. crystal, rock). — **Spatial organization** - Space arrangements are defined by computer-based analyses of natural conditions (e.g. humidity, temperature, winds). — **Technological solutions** Implementation of natural ventilation systems, whenever possible combined with advanced blue-green infrastructures. Green roofs and walls. Applying rules of bioclimatic design with primary focus on proper adjustment of buildings and spaces to local biological and climatic conditions with aim to use available contemporary technology to provide user with the highest level of comfort at the minimal environmental costs without compromising the rights of future generations to benefit from the same level of comfort.	70 (Good)
The new building project complies with the features of the eco-architecture style to attain the good performance and reflects ***at least three*** of the following additional features related to the ‘semantic and theoretical framework’ category: — **Semantic and theoretical framework** Idea of the need to adopt a sustainable style of life. Design of built environment as an aesthetic, technological and moral issue. Reconsideration of vernacular architecture as a model for sustainable architecture.	100 (Excellent)

Biological and regenerative design aimed at natural ecosystem restoration by creating multilevel synergies with the built environment. Considering biological and environmental theories (e.g. theories of resilience and autopoietic systems) as new perspectives on environment and human-nature relationships.	
AS metric score = Selected sub-metric score	**AS = 0 or 40 or 70 or 100**

Source: JRC.

Table 149. Actual style (AS) metric score - Contemporary modernism.

Sub-metric	**Score**
*If the **contemporary modernism** style has been identified as the most used style of the project, select single value below.*	
The new building project does not demonstrate any features of the contemporary modernism style.	0 (Low)
The new building project is characterised by the following basic features of the contemporary modernism style: — **Shapes** - Basic shapes derived from Euclidean geometry (e.g. rectangles, squares, cubes, spheres). — **Colour** - Analogous colours (especially shades of white and grey, contrast of black/grey/white). — **Material and texture** - Smooth surfaced and textures manifesting use of contemporary materials). — **Composition** - Shapes and patterns arranged in repetitive modules. — **Spatial organization** - Open-plan spaces.	40 (Acceptable)
The new building project is characterised by the following basic features of the contemporary modernism style: — **Shapes** – Shapes and patterns based on proportion of the classical Greek and Roman architecture (e.g. golden section, Fibonacci sequence). — **Colours** - Harmony based on monochromatic surfaces of analogous colours with elements of natural colours of building materials, with abundant introduction of green plants and the colour of water in buildings and spaces. — **Composition** – Shapes and patterns are arranged in such a way as to create contrasts of vertical and horizontal lines and/or light and heavy masses. **Spatial organisation** - Space arrangements facilitating use and circulation.	70 (Good)
The new building project complies with the features of the contemporary modernism style to attain good performance and reflects ***at least three*** of the following additional features related to the 'semantic and theoretical framework' category: — **Semantic and theoretical framework** Ideas that "form follows function" and/or "less is more". Rationality as the basis for achieving harmony of design, space and function. Reference to architectural theories that attempted to impose a rational order on human life and the built environment (e.g. Le Corbusier's (Le Corbusier, (1923), Walter Gropius's (1965) theories). Artistic theories as sources of aesthetic ideals (e.g. abstractionism, neoplasticism, suprematism).	100 (Excellent)
AS metric score = Selected sub-metric score	**AS = 0 or 40 or 70 or 100**

Source: JRC.

Table 150. Actual style (AS) metric score - Deconstructivism

Sub-metric	**Score**
*If the **deconstructivism** style has been identified as the most used style of the project, select single value below.*	
The new building project does not demonstrate any features of the deconstructivism style.	0 (Low)
The new building project is characterised by the following basic features of the deconstructivism style: — **Shape** - Shapes made of decomposed or shattered elements. — **Colour** - Primary colours (black, red, grey, and white). — **Textures and materials** - Light-reflecting surfaces and/or rusted surfaces. — **Composition** – Shapes and surfaces juxtaposed one to another in a contrasting manner. — **Spatial organization** - Continuous spaces without clearly defined boundaries.	40 (Acceptable)
The new building project is characterised by the following basic features of the deconstructivism style: — **Shape** - Shapes, patterns and composition imitating actions of physical forces or tensions (e.g. wave- or fold-like shapes). — **Colours** - Limited palette based on colours contrasting with one another or with the colours dominant in the surroundings. — **Textures and materials** - Reflective and/or rusty surfaces; contrasting textures and materials. — **Composition** - Shapes and patterns are arranged in multiple-layers imposed one on another and/or masses juxtaposed one to another so as to imitate a collision of large bodies.	70 (Good)

— **Spatial organisation** - Space arrangements disrupting users' expectations and habits. — **Technological and structural solutions** - Solutions allowing for constructing slanted walls and/or walls and roofs based on non-Euclidean geometry (e.g. cantilevered constructions, parametric design).	
The new building project complies with the features of the deconstructivism style to attain the good performance, and reflects ***at least three*** of the following additional features related to the 'semantic and theoretical framework' category: — **Semantic and theoretical framework** Idea that cultural canons, standards, or values are relative. Idea that architecture is a powerful tool to create new lifestyles. A contradiction to the ideals of modernism. Theories of architecture as a means of reinterpreting (deconstructing) users' understanding of space in social and physical terms (e.g. Charles. Jencks' theories (Jencks, 1988)). Philosophical theories (e.g. Jacques Derrida's deconstruction (Derrida, 2017)) or scientific theories (e.g. catastrophe theory, entropy theory) that provide the basis for a new view of the social and natural world.	100 (Excellent)
AS metric score = Selected sub-metric score	**AS = 0 or 40 or 70 or 100**

Source: JRC.

Table 151. Actual style (AS) metric score - Regionalism.

Sub-metric	**Score**
*If the **regionalism** style has been identified as the project style, select single value below.*	
The new building project does not demonstrate any features of the regionalism style.	0 (Low)
The new building project is characterised by the following basic features of the regionalism style: — **Shape** - Shapes and patterns continuous with the shapes of the cultural or natural surrounding landscape. — **Colour** - Colours continuous with the colours of the cultural or natural surrounding landscape. — **Textures and materials** - Use of local materials (e.g. clay, stone, wood). — **Composition** - Forms and colours arranged to create unity (harmony) with the surroundings. — **Spatial organization** - Imitation of space arrangements typical for the local (vernacular) architectural tradition.	40 (Acceptable)
The new building project is characterised by the following basic features of the regionalism style: — **Shape** - Shapes and patterns imitating shapes and patterns typical for the local (vernacular) architectural tradition. — **Colours** - Palette of colours typical for the local (vernacular) architectural tradition, as well as natural and cultural landscape. — **Textures and materials** - Local materials (e.g. clay, stone, and wood), abundant introduction of greenery, and local patterns (e.g. wood carvings, ceramics, etc.). — **Composition** - Shapes are arranged to enhance a multisensory experience of the design and its surroundings (e.g. solutions using light/shade effects or aimed at creating a pleasant soundscape). — **Spatial organisation** - Space arrangements create unity between the building and its surroundings (e.g. through the use of porticos, large windows, terraces).	70 (Good)
The new building project complies with the features of the regionalism style to attain the good performance, and reflects ***at least three*** of the following additional features related to the 'semantic and theoretical framework' category: — **Semantic and theoretical framework** Idea that it is necessary to appreciate local cultural or natural landscape. Idea that *genius loci* is to be respected. Theories of architecture as a means to understand the value of the experience of local culture and landscape (e.g. Kenneth Frampton's (Frampton, 1983), Juhani Pallasmaa's (Pallasamaa, 1988), Peter Zumthor's (Zumthor, 1999) theories). Psychological or philosophical theories (e.g. Christian Norberg-Schulz's phenomenology (Norberg-Schulz, 1980)) or theories of cultural and natural heritage management and preservations as theories offering new insights into the understanding of how people relate to places and spaces.	100 (Excellent)
AS metric score = Selected sub-metric score	**AS = 0 or 40 or 70 or 100**

Source: JRC.

Design tendency (DTen) metric refers to actual trends that, apart from their aesthetic value, measurably contribute to the well-being of humans and their relationship with the natural environment. These trends are clearly outlined in various ecological approaches and biophilic design, which relates to the biological tendency of humans to stay in relationship with nature. Research shows that the use of the biophilic approach to design the urban environment has a positive impact on the well-being of the natural environment (Kellert et al., 2008).

The design tendency metric relies on the biophilic approach as relevant design trend and assesses whether a new building project includes nine design solutions strictly related to the biophilic design approach. The presence or absence of each of the nine design solutions in a project provides nine partial scores, each corresponding to a positive (in the case of presence) or a zero (in the case of absence) value, which are assigned according to the rationale presented in Table 152. The sum of the nine partial scores, providing the design tendency metric score, ranges from 0 (i.e. absence of all biophilic design solutions) to 100 (presence of all biophilic design solutions).

Table 152. Design tendency (DTen) metric score.

Sub-metric	**Score**
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the nine design solutions below and sum the corresponding nine scores	
The project includes the following design solutions related to biophilic design:	
1. Exposure to natural light, including filtered and diffused light, reflected light, light pools or others.	If yes, + 15. If no, 0.
2. Exposure to greenery/presence of plants in the building interiors (direct contact with greenery).	If yes, + 15. If no, 0.
3. Use of natural materials (such as wood, stone) and colours (such as earth tones, and others found in the natural environment).	If yes, + 15. If no, 0.
4. Green technology systems (e.g. 'vegetated green systems', 'living walls').	If yes, + 15. If no, 0.
5. Formal aesthetic references to the natural world, such as patterns, geometry, rhythms, ornamentation.	If yes, + 8. If no, 0.
6. Access to open water inside or outside the building.	If yes, + 8. If no, 0.
7. Solutions relate to the geography of the surroundings, e.g. emphasising/adapting to geological features of the location, views of buildings and landscapes, relations to the local environment.	If yes, + 8. If no, 0.
8. Solutions that relate to the historical and cultural context of the site, contained for example in aesthetic references to the culture of the region, use of material, attention to the relationship with the surroundings.	If yes, + 8. If no, 0.
9. Presence of art in the designed space.	If yes, + 8. If no, 0.
Design tendency (DTen) metric score = Σ (sub-metric scores = 'yes', 'no' scores)	**0 ≤ DTen ≤ 100**

Source: JRC.

4.14.3 Example (B.11)

The same building considered for the evaluation of B.7 KPI (Section 4.10.4) is also used for the evaluation of B.11 KPI. The building description is provided again in the following to facilitate the evaluation of B.11 KPI. A free-standing public building, newly constructed in a historic environment is considered. The four-storey building houses a contemporary art museum, shops, restaurants and artist studios. The scale of the building was adapted to the neighbouring buildings. The building is designed as a quadrangle with an inner courtyard, which is open to the general public (not exclusively to the direct users of the building). The courtyard forms part of the public space and the ground floor of the building is largely open (the structural elements of the building are visible). The courtyard features a green area and a water reservoir (e.g. fountain, small pool, etc.), as well as an open-air amphitheatre and an outdoor art exhibition. The building exhibits several features of the contemporary modernism style, with its façades heavily glazed, rectangular forms, monochromatic colours specific for the building materials used. Additionally, a number of pro-ecological solutions in line with the biophilic design approach can be observed, including exposure to natural light (diffused due to the building function), greenery in the interiors, natural materials in the interior arrangement, vertical green systems (VGS) and water body for evaporative cooling.

The evaluation of B.11 depends on the score of the cognitive experience (B.11.1) indicator, which is evaluated through the following two metrics: (*i*) actual styles (AS) and (*ii*) design tendency (DTen).

Actual style metric is evaluated by comparing the design solutions of the example building to the basic features of the contemporary modernism style, according to the sub-metrics in Table 149, as the building design mainly reflects the contemporary modernism style (Table 147). Based on the comparison results, the actual style score is equal to 70.

Design Tendency metric is evaluated according to the sub-metrics in Table 152. The design tendency score is based on the presence of seven out of nine design solutions related to the biophilic design approach, as reported in Table 153.

Table 153. Example of *design tendency* evaluation.

Sub-metric	Score
Indicate the presence, i.e. yes, or absence, i.e. no, of each of the nine design solutions below and sum the corresponding nine scores	
The project includes the following design solutions related to biophilic design:	
1. Exposure to natural light, including filtered and diffused light, reflected light, light pools or others.	Yes, + 15.
2. Exposure to greenery/presence of plants in the building interiors (direct contact with greenery).	Yes, + 15.
3. Use of natural materials (such as wood, stone) and colours (such as earth tones, and others found in the natural environment).	Yes, + 15.
4. Green technology systems (e.g. 'vegetated green systems', 'living walls').	Yes, + 15.
5. Formal aesthetic references to the natural world, such as patterns, geometry, rhythms, ornamentation.	No, 0.
6. Access to open water inside or outside the building.	Yes, + 8.
7. Solutions relate to the geography of the surroundings, e.g. emphasising/adapting to geological features of the location, views of buildings and landscapes, relations to the local environment.	No, 0.
8. Solutions that relate to the historical and cultural context of the site, contained for example in aesthetic references to the culture of the region, use of material, attention to the relationship with the surroundings.	Yes, + 8.
9. Presence of art in the designed space.	Yes, + 8.
Design tendency (DTen) metric score = Σ (sub-metric scores = 'yes', 'no' scores)	**DTen = 84**

Source: JRC.

Having evaluated the score for each metric, B.11.1 score is estimated according to Equation (239). B.11.1 corresponds to B.11 score (Equation (238)), which is estimated equal to 78.4, thus corresponding to a *Good* performance class (Figure 101), as reported in Table 154.

Table 154. Example of B.11.1 and B.11 evaluation.

Indicator	**B.11.1**
Indicator score	= 0.40 · 70 + 0.6 · 84 = 78.4
B.11 score	= 1 · 78.4 = 78.4
B.11 performance class	Good
B.11 performance class score ($PCS_{B.11}$)	70

Source: JRC.

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List of abbreviations and definitions

AC	Attractiveness of circulation
AC_b	Attractiveness of circulation at building scale
$AC_{n/u}$	Attractiveness of circulation at neighbourhood/urban scale
Accessibility	Provision of buildings, parts of buildings, or outdoor built environments for people, regardless of disability, age or gender, to be able to gain access to them, into them, to use them and exit from them.
Accessible format	Adoption of different presentations to make information accessible using another sensory ability, e.g. visual information presented in audio and tactile formats, audio information presented in visual formats.
AEC	Architectural Engineering and Construction.
Aesthetic experience	Special state of mind that is qualitatively different from the everyday experience (Marković, 2012).
A_{eq}	Effective absorbing area.
AGS	Australian Geomechanics Society
AI	Artificial Intelligence.
Aperture	In the basic meaning - a window, door, other opening that provides a controlled connection between the interior and the exterior of a building. In the conceptual meaning - an aperture is a frame portal, passage, oculus, gap, cleft, chasm, valve or void. At the neighbourhood/urban scale, openings in buildings or gaps between building masses can be considered as apertures (Ching, 2015).
AR	Auditory richness
AS	Actual styles
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASI	Austrian Standards International
Assistive technology / device	Piece of equipment, product, system, hardware, software or service that is used to increase, maintain or improve functional capabilities of persons with disabilities.
Attentive	Paying close attention, mindful (Marković, 2012).
Authenticity	Authenticity is a quality possessed by individuals and defined as being original, true, sincere, genuine, and authoritative (Jokilehto, 2006; Sekler, 2010).
Axis composition	The arrangement of forms on either side of a line (visible or imaginary), which can symbolise structure, movement, direction, line of rotation, etc. In a composition, forms and masses can be arranged either asymmetrically or symmetrically. Axes are used for the balanced organisation of elements in architectural and urban design projects. There can be multiple axes and compositional orders in a design (Ching, 2015).
B	Beauty dimension.
BAMB	Buildings as Material Banks
BE	Biodiversity Enhancement
BEMS	Building Energy Monitoring Systems
BIM	Building Information Modelling
BoM	Bill of Materials
BoQ	Bill of Quantities
BRE	Building Research Establishment
BSI	British Standards Institution
C	Contrast
CAM	Italian Minimum Environmental Criteria
Cavity barrier	A construction within a cavity, other than a smoke curtain, to perform either of the following functions. • Close a cavity to stop smoke or flame entering. • Restrict the movement of smoke or flame within a cavity.
CCT	Lighting Correlated Colour Temperature
CEN	Comité Européen de Normalisation

CFD	Computational fluid dynamics
CIE	International Commission on Illumination
CITES	Convention on International Trade in Endangered Species
CLC	Construction Leadership Council
CLT	Cross-Laminated Timber
Cognitive	Cognitive relates to, or involves conscious mental activities; and includes thinking, understanding, learning and remembering. Semantic, symbolic and imaginative aspect of aesthetic experience (Marković, 2012).
Coherence	Consistency and complementarity of the building units of a collective form in scale (grain) and setting (close interaction) (Alexander et al., 1987; Salingaros, 2000; Ewing et al., 2013).
COM	Commission communication
Compactness	Combined quality of the built fabric based on indicators of density, diversity (form and use), intensity (UK Urban Task Force, 1999).
Compartment (fire)	Compartment (fire) A building or part of a building, comprising one or more rooms, spaces or storeys, that is constructed to prevent the spread of fire to or from another part of the same building or an adjoining building.
Continuity	Clarity of space via framing frontages of the buildings with minimum break by wide openings (Hedman and Jaszewski, 1984, EPOA, 1997).
CP	Coherence with local spatial and strategic planning
CRED	Centre for Research on the Epidemiology of Disasters
Cultural heritage	A group of resources inherited from the past which people identify, independently of ownership, as a reflection and expression of their constantly evolving values, beliefs, knowledge and traditions. It includes all aspects of the environment resulting from the interaction between people and places through time (Council of Europe, 2005).
D	Dimension
Daylight factor	Ratio of the illuminance at a point on a given plane due to the light received directly or indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, excluding the contribution of direct sunlight to both illuminances daylight provision level of illuminance achieved across a fraction of a reference plane for a fraction of daylight hours within a space. The factor is calculated according to EN 17037 (CEN, 2021e).
DBO	Design, Build and Operate
DC	Density Compatibility
Density	The ratio between the built-up area (coverage or floor space) and the development site area (March and Martin, 1972, Rådberg, 1996, Pont and Haupt, 2010).
DGP	Daylight Glare Probability
DHLGH	Department of Housing, Local Government and Heritage, Ireland
DIN	Deutsches Institut für Normung
DLUHC	UK Department for Levelling Up, Housing & Communities
DT	Digital Twins
DTen	Design Tendency
E	Edges
$\bar{E}$	Target illuminance level
ECSO	European Construction Sector Observatory
$\bar{E}_m$	Maintained illuminance
EMAS	EU Eco-Management and Audit Scheme
Emergency lighting	Lighting for use when the power supply to the normal lighting fails
$\bar{E}_{min}$	Minimum illuminance level
EPD	Environmental Product Declarations
EPOA	Essex Planning Officers Association
Escape lighting	The part of the emergency lighting that is provided to ensure that the escape route is illuminated at all times

EU	European Union
EUTR	European Union Timber Regulations
FAR	Floor area ratio
FEMA	Federal Emergency Management Agency
fib	Fédération internationale du béton
Fire resisting (Fire resistance)	The ability of a component or a building to satisfy, for a stated period of time, some or all of the appropriate criteria given in the relevant standard. Fire resistance is measured in minutes, and relates to time elapsed in a standard test, which should not be confused with real time.
Firefighting lobby	A protected lobby that provides access from a firefighting stair to the accommodation area and to any associated firefighting lift.
Firefighting shaft	A protected enclosure that contains a firefighting stair, firefighting lobbies and, if provided, a firefighting lift together with its machine room.
Firefighting stair	A protected stairway that connects to the accommodation area through only a firefighting lobby.
Fire-separating element	A compartment wall, compartment floor, cavity barrier and construction that encloses a protected escape route and/or a place of special fire hazard.
Fire-stop (Fire-stopping)	A seal provided to close an imperfection of fit or design tolerance between elements or components, to restrict the spread of fire and smoke.
FLEGT	Forest Law Enforcement Governance and Trade
FSC	Forest Stewardship Council
g	Self-weight
g_2	Additional permanent load
GCC	Gross Construction Cost
GHG	Greenhouse Gas
GI	Green infrastructure Integration
GIFA	Gross Internal Floor Area
GIS	Geographic Information System
Glare	Condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of luminance, or by extreme contrasts.
GMPE	Ground Motion Prediction Equations
Going (ramp)	Horizontal distance between the start and finish of a flight of a ramp
Going (stair)	Horizontal distance between two consecutive nosings, measured on the centre line.
GPP	Green Public Procurement
GWP	Global-Warming Potential
h	Hazard
Hazard intensity	The size of a hazard represented by the value of a Hazard Intensity Measure.
Hazard Intensity Measure	A measurable hazard characteristic that is used for engineering design
Hierarchy	In architecture, hierarchy refers to the arrangement of forms, masses and spaces in a fixed order - from the most to the least important. Hierarchy is used to emphasise/expose a particular element(s) in a composition and is most often established by means of size, shapes, colours or placement (Ching, 2015).
Historic urban landscape	The historic urban landscape is embedded with current and past social expressions and developments that are place-based. It is composed of character-defining elements that include land uses and patterns, spatial organization, visual relationships, topography and soils, vegetation, and all elements of the technical infrastructure, including small scale objects and details of construction (e.g. curbs, paving, drain gutters, lights, etc.) (UNESCO, 2005).
HV	Heritage Value
HVAC	Heating, Ventilating and Air Conditioning
IAEA	International Atomic Energy Agency

IBEC	Institute for Building Environment and Energy Conservation
IC	Increased areas under Canopy cover
IEC	International Electrotechnical Commission
IES	Illuminating Engineering Society
IIC	Impact Insulation Class
IIS	Interaction with Immediate Surroundings
IM	Hazard Intensity Measure
INGV	National Institute of Geophysics and Volcanology in Italy
Integration	Fewest changes (number of turns and angular variations) and least movement distance through links among all nodes in a network (Hillier and Hanson, 1984; Hillier, 2005).
Integrity	A measure of the overall coherence and the wholeness and intactness of the property and its attributes (ICOMOS, 1975).
Internal linings	The materials or products used in lining any partition, wall, ceiling or other internal structure.
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IRDR	Integrated Research on Disaster Risk
IS	Integration with Surroundings
ISO	International Organization for Standardization
IWBI	International WELL Building Institute
KPI	Key Performance Indicator
L	Landmark
Landscape	Cultural properties which represent the *"combined works of nature and of man"*. Illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal (UNESCO, 1972, 2005, 2011; Council of Europe, 2000; Menary, 2010; Bandarin and van Oers, 2012, 2015; Greffe, 2012; Dobričić and Acri, 2017, 2021; Dobričić et al., 2019).
LCA	Life Cycle Analysis
LCC	Life Cycle Costing
L_{den}	Day-evening-night level
LRV	Light Reflectance Value (also known as the luminance reflectance factor)
Luminance	Intensity of light emitted or reflected in a given direction from a surface element divided by the apparent area of the element in the same direction.
Luminance contrast	Luminance of one surface or component compared to the luminance of the background or adjoining surface.
LVL	Laminated Veneer Lumber
M	Rate of metabolic energy production
Massing	Massing refers to the spatial forms of a building, contained in three dimensions. Masses are not two-dimensional surfaces, but volumes. The term can be applied to the building as a whole or to its elements, which are characterised by a certain distinctiveness (achieved, for example, by the use of a different colour, shape or translucency of the mass). "Visually light" masses are usually characterised by the use of light colours, transparency (of glass), reduced size in relation to neighbouring volumes or other building elements. "Heavy" masses are recognised by dark colours (often the use of materials such as stone or concrete), low transparency, and dominant volume (Jacoby, 2016).
MEP	Mechanical, Electrical and Plumbing services
MHCLG	UK Ministry of Housing, Communities & Local Government
MMC	Modern Methods of Construction

Moving walk	Power-driven installation for the conveyance of persons in which the user carrying surface remains parallel to its direction of motion and is uninterrupted.
MRI	Mean Recurrence Interval, (also called Return Period or Recurrence Interval), refers to the average time between hazard events.
Multisensory	Involving or using more than one of sense (Haverkamp, 2012).
N	Novelty
NEB	New European Bauhaus
NIC	National Intelligence Council
Nosing	Front edge of a tread or landing that can be rounded, chamfered or otherwise shaped.
NRC	Noise Reduction Coefficient
O	Order
OID	Observatoire de l'immobilier durable
OMC	Open Method of Coordination group of EU Member State experts
OR	Olfactory richness
OS	Open space
OSB	Oriented Standard Board
OSC	Open Space Connectivity
P	Path
Patina	Patina is defined as a tangible layer of authenticity and integrity, the skin of the work of art, a surface appearance (as a colouring or mellowing) of something grown beautiful, especially with age or use (Brandi, 2000).
PCS	Performance Class Score
PEFC	Programme for the Endorsement of Forest Certification
PEGS	Preserved or Enhanced original, historic Green Spaces
PGA	Peak ground acceleration
PKF	Preserved Key Features of the building or space
PMC	Pre-manufactured product and material costs
PMV_a	Pre-Manufactured Value
PMVo	Predicted Mean Vote
PO	Preserved original/historic Openings
PP	Preserved Patina
PPD	Public Procurement Directive
Protected corridor/lobby	A corridor or lobby that is adequately protected from fire in adjoining areas by fire resisting construction.
Protected entrance hall/landing	A circulation area, consisting of a hall or space in a flat, that is enclosed with fire resisting construction other than an external wall of a building.
Protected shaft	A shaft that enables people, air or objects to pass from one compartment to another, and which is enclosed with fire resisting construction.
Protected stairway	A stair that leads to a final exit to a place of safety and that is adequately enclosed with fire resisting construction. Included in the definition is any exit passageway between the foot of the stair and the final exit.
Proxemics	Human use of space and the effects that population density has on behaviour, communication and social interaction (Hall, 1990).
PRGS	Preserved or Recovered original, historic Green Spaces
PSE	Preserved original/historic Structural Elements
PSHA	Probabilistic Seismic Hazard Assessment
q	Imposed load
Q_{dec}	Actual quantity of deconstructed element
Q_{total}	Total quantity of deconstructed elements
RCA	Re-development of Contaminated Areas

RDA	Re-development of functionally Devalued Areas
Reference plane	Plane in a space on which illuminances and/or daylight factors are calculated, specified, or measured.
Rhythm/repetition	Rhythm is determined by the use of repeated forms. In architecture, repetition usually refers to a pattern in which the same shape, size, and colour is used repeatedly throughout a project. In the case of repetition, the shapes remain constant; in the case of rhythm, they change, but are still recognisable (Hashimoto, 2004).
RS	Rareness of landscape/heritage Site types
SA	Sense of Attachment
SDOF	Single-Degree-Of Freedom
sec	Second
SFoC	Swiss Federal Office of Culture
SP	Scale and Proportion
Stand-off distance	The distance between the blast and the structure.
STI	Speech Transmission Index
Surface	The external (visible) surface of elements that frame an architecture or space, i.e. walls, ceilings, floors, other structural elements and furnishings (Jacoby, 2016).
T	Reverberation time.
TLPR	Traditional cultivated Landscape Preservation and Restoration
T_{mr}	Mean radiant temperature.
TR	Tactile Richness
Tran	Transparency
Transformation	A kind of repetition of form, a modification in response to certain conditions without changing the coherence of the whole concept. Shapes can be stretched, enlarged, reduced, rotated, etc. (Ching, 2015).
TWSI	Tactile Walking Surface Indicator
UGR	Unified Glare Rating
UN	United Nations
UNDRR	United Nations office for Disaster Risk Reduction
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN-Habitat	United Nations Human Settlements Programme
UNI	Ente Italiano di Normazione
Universal design	Design of products, environments, programmes and services to be usable by all people, to the greatest extent possible, without the need for adaptation or specialised design.
U_o	Uniformity of illuminance
Usability	Extent to which a product, a service and the built environment can be utilised by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a given context of use.
USGBC	US Green Building Council
USGS	United States Geological Survey
Veiling reflections	Specular reflections that appear on the object viewed and that partially or wholly obscure the details by reducing contrast.
Visual contrast	Perception of a difference, visually, between one surface or element of a building and an adjacent surface or element.
VR	Virtual/Augmented Reality
VisR	Visual Richness
w	weight
W	Mechanical Work

Wayfinding	Features in a building or outdoor built environment that facilitate orientation (knowing where you are in an environment) and navigation (planning and following a route from one place to another).
WCDRR	World Conference on Disaster Risk Reduction
WHO	World Health Organisation

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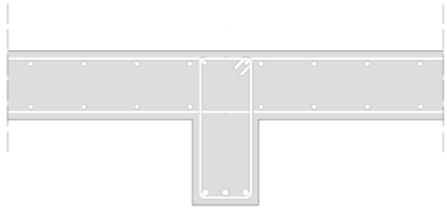
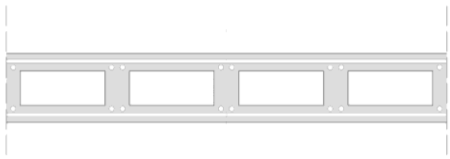
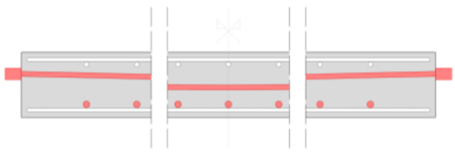
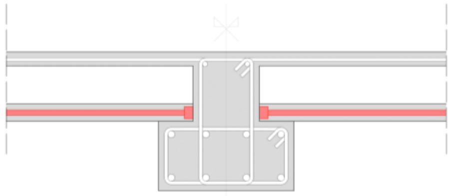
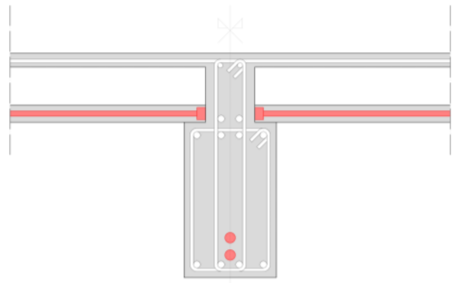
Annex A Supplement to Chapter 4

Table A. 1. Example of floor slab systems.

Reinforced Concrete Floor Systems	
a) Biaxial flat plate Biaxial flat plates offer simplified formwork and construction processes. They provide flexibility in the architectural layout due to the absence of beams, resulting in reduced construction time and cost. However, these plates have limited span capacity compared to other systems. They require careful consideration of deflections and punching shear, making them potentially unsuitable for heavy loads or long spans (Schneider et al., 2024; CEN, 2010).	
b) Uniaxial plate, deep beams Uniaxial plates with deep beams offer increased span capacity compared to flat plates. They allow for greater architectural flexibility and can accommodate heavier loads and longer spans, good practice follows the rule of short-span beams (5-7 m) and long-span floors (7-9 m). However, they involve a more complex formwork and construction process compared to flat plates, making it challenging to accommodate mechanical, electrical and plumbing (MEP) services such as ductwork, piping, and electrical conduits. The added complexity may lead to increased material and labour costs (Schneider et al., 2024; CEN, 2010).	
c) Biaxial voided plate Biaxial voided plates reduce material usage due to voids, resulting in significant material savings. They offer improved structural efficiency and span capacity and provide enhanced thermal and acoustic insulation properties. However, they require specialised formwork to create the voids and increased coordination for MEP installations. This can lead to higher construction time and costs. The inclusion of voided polypropylene fittings is often an impediment to recyclability (Daliform Group, 2022; Beres and Mota, 2014).	
d) Post-tensioned flat slab Post-tensioned flat slabs offer greater span capacity and reduced deflections compared to conventional flat slabs. They allow for longer spans and thinner slabs, resulting in material savings and improved resistance to cracking and durability. However, they involve a higher initial cost due to prestressing tendons and specialised construction techniques. They also require skilled labour and higher quality control during construction and offer limited flexibility for alteration after installation (VSL International, 2015; Friedrich, 2018).	
f) Coffer slab (also referred to as waffle slab) Similar to biaxial voided slabs, coffers are employed as void formers to create ribs. Also known as waffle slab, it consists of a series of sunken panels or indentations formed on the underside of the concrete slab. These recessed areas are typically arranged in a grid pattern. Differently from voided slabs, the formwork is removed, creating ribs that are typically reinforced. Coffer slabs are very efficient for long-span configurations. However, formwork fabrication and removal is more complex compared to other solutions.	
e) Deep beams, prestressed hollow-core slab Combining deep beams with prestressed hollow-core slabs offers increased strength and stiffness, longer spans, and reduced material usage. It also enhances fire resistance and acoustic performance. However, it requires more complex structural detailing and coordination for MEP installations (Hollow Core Concrete, 2004; CEN, 2011a).	

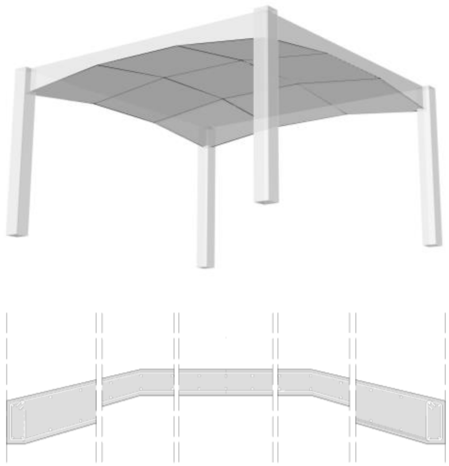
f) Post-tensioned deep beams, prestressed hollow-core slab

Implementing post-tensioning with prestressed hollow-core slabs is highly effective for long-span floors. By employing optimised beams along the longer spanning direction and addressing long-term deflection and resistance concerns through post-tensioning, the prestressed hollow-core slabs can be oriented in the shorter span direction. This orientation leads to a reduction in cross-section and material usage. This system allows for greater structural efficiency and optimised resource utilization for long-span applications. (Hollow Core Concrete, 2004; Friedrich, 2018; CEN, 2011a).



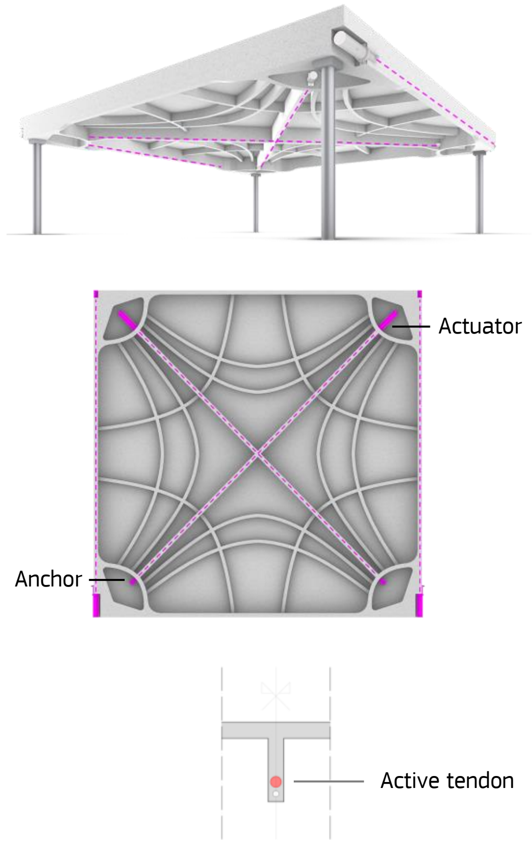
g) Vaulted slabs

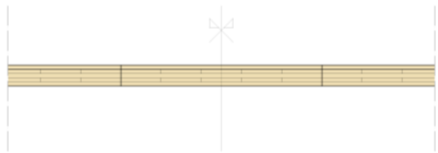
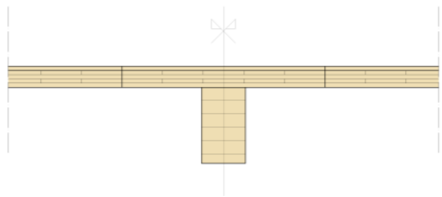
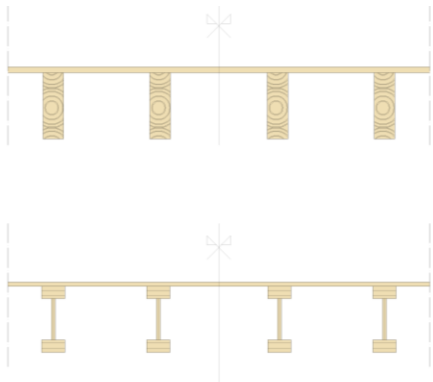
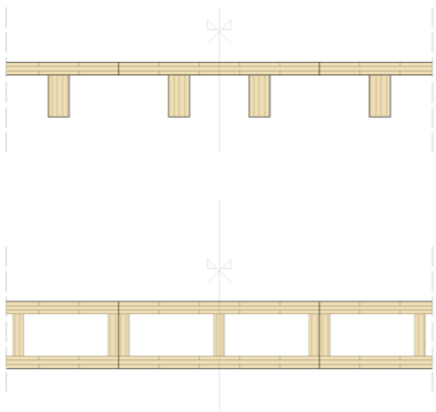
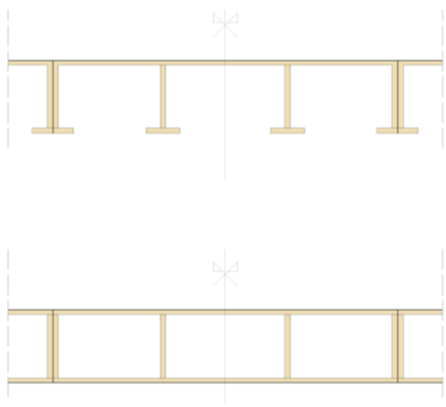
Vaulted slabs are efficient because the load action is transferred primarily though compression forces reducing bending moments and shear forces to a minimum. The load is typically transferred to specific points (e.g. the corners) allowing for efficient material use. Designing vaulted slabs typically requires a relatively more complex workflow compared to flat slabs including careful consideration of geometry, support conditions, and applied loads to ensure structural stability and performance (Rippmann et al., 2018; Hawkins et al., 2019).

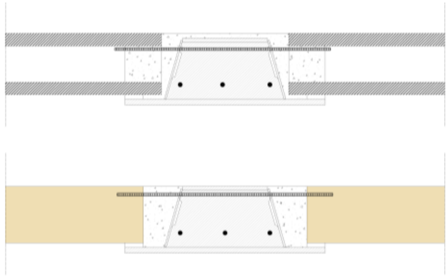
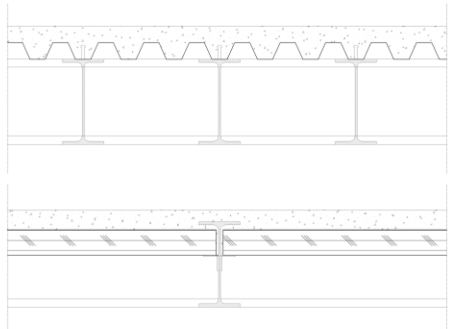
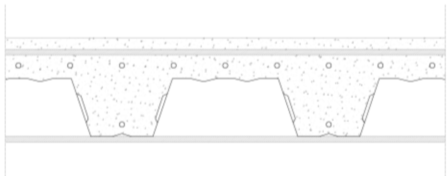
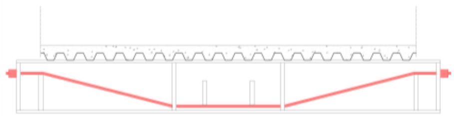


h) Adaptive ribbed slabs

Active structural control can be employed to achieve drastic material savings at the expense of small operational energy that is required to reduce the response under strong loading events (Senatore et al., 2019). Adaptive structures incorporate sensors and actuators to monitor responses and adjust control forces to satisfy relevant limit states. In the case of ribbed floor slabs, active tendons can be strategically integrated in the ribs. The tendons are positioned following a profile so that the tension force is applied eccentrically to the neutral axis of the slab-ribs assembly. The resulting system of forces causes a bending moment that counteracts the effect of the external load (Reksowardojo et al., 2024). When combined with careful design, the ability to reduce the response improves load-bearing capacity and minimise cracking, enhancing resilience and durability. Reliability and maintenance costs of the active system must be considered.



Timber Floor Systems	
a) Biaxial CLT slab Biaxial Cross-Laminated Timber (CLT) provides high flexibility in floor layout with column grids spanning up to 8 · 8 m achieving a beam-free timber frame with slender, point-supported slabs (Zöllig et al., 2016). The main structural limitation concerns the bend-resistant joining of cross-laminated modules which might require a larger section thickness with respect to uniaxial-deep-beams solutions. Relying on a high degree of prefabrication and patented processes, this technology currently has limited market availability (Best Wood Schneider, 2023; Timber Structures 3.0, 2022).	
b) Uniaxial CLT slab The combination of uniaxial Cross-Laminated Timber (CLT) and deep timber beams allows for the construction of large and flexible floor spans. This solution performs best when floor and wall panels are combined forming a monolithic structure. Speed of construction and potential for prefabrication make of this technology a high-performance and cost-effective solution (Best Wood Schneider, 2023; Schneider et al., 2024).	
c) Joist timber slab Timber floor joists is a simple and cost-effective construction solution for residential and commercial slabs. The system consists of parallel timber beams topped by a thin sheathing panel, typically oriented standard board (OSB) or massive lumber, which can be considered as an integral part of the cross-section according to the type of connection at the interface. This system allows for quick installation and flexibility in floor layouts. Engineered I-joists can enhance material performance reaching long spans by maximising the strength-to-material ratio. Usually, to ensure an adequate performance, a considerable structural depth is required (Jelušič and Kravanja, 2022).	
d) Box CLT slab Uniaxial Box (or hollow-core) CLT slabs are variations of cross laminated timber floor systems that feature a hollow or voided core within the CLT cross-section. This is achieved by combining thin horizontal panels with vertical ribs which are mechanically joined or glued forming high-performance composite units that maximise the stiffness-to-weight ratio allowing for thinner slabs and longer spans. (Best Wood Schneider, 2023; Schneider et al., 2024).	
e) Box LVL slab Laminated veneer lumber (LVL) construction provides high strength and stiffness offering, homogeneous material properties, good dimensional stability, and resistance to warping or shrinkage. LVL sabs can be designed for spans up to 15 m (24 m for roofs) and heavy loads. Limited availability of large LVL panels specialised manufacturing may impact design flexibility (Best Wood Schneider, 2023; Stora Enso, 2021).	

Composite Floor Systems	
a) Steel-concrete composite slim-floor beams, uniaxial prestressed hollow-core slab / uniaxial CLT slab This system combines steel-concrete composite slim-floor beams with different uniaxial spanning slab technologies. Lightweight solutions comprise prestressed hollow-core concrete slabs and Cross-Laminated Timber (CLT) slabs. The slim composite floor beams are connected to concrete or timber slab elements by means of in-situ casting, ensuring efficient load transfer without the need for down-stand elements. Advantages include reduced floor depth, longer spans, and fast construction thanks to precast elements (Schäfer et al., 2018; Peikko Deutschland, 2023).	
b) Uniaxial steel-concrete composite slab with (non-) collaborating metal sheets. This system involves a combination of steel and concrete where embossed metal sheets act as permanent formwork and are commonly placed on steel beams. Concrete is poured onto the metal sheets, forming a composite slab. Advantages include simplicity, cost-effectiveness, and suitability for shallow floor systems. In a collaborating cross-section, special connectors guarantee coupling to the steel girder, thus providing lateral stability and enhancing stiffness and resistance by effectively utilising the characteristics of each material. In a non-collaborating version, the metal sheet can be placed freely along the girder's depth, thus achieving a lower thickness of the overall floor system at the cost of a lower load-bearing performance. The use of metal sheets may require additional fire protection coatings. (Schäfer et al., 2018; Schneider et al., 2024).	
c) Uniaxial deep steel-concrete composite deck As for uniaxial steel-concrete composite slabs, this solution implements optimized embossed metal sheets and concrete for an effective material combination. Deeper ribs with respect to ordinary sheet profiles allow for long spans without the need of secondary beams, multi-span configurations are also achievable. (Montana Bausysteme, 2021; Schneider et al., 2024).	
d) Post-tensioned steel beams, Uniaxial steel-concrete composite slab with collaborating metal sheets. Implementing uniaxial steel-concrete composite slabs with collaborating metal sheets on post-tensioned steel deep beams is highly effective, especially in long-span floors. In this case, the post-tensioned beams take the longer bay direction, while the supported composite slab spans transversally to the beams. While requiring specialised processes and higher quality control, this system enables a significant increase of structural efficiency and resource utilization reduction. As for any (post-tensioned) steel-concrete composite component, long-term behaviour must be considered (Schneider et al., 2024).	

Source: JRC.

Chapter 5: Inclusiveness

5 Inclusiveness

5.1 Introduction

Social inequalities have been a permanent characteristic of modern societies based on the fundamental division between those in possession of means of production and those with the only option of selling their working power in the labour market. During the three centuries of the modern era, social inequalities have been regulated in rough ways, including wars, economic crises and depressions, and revolutions. Inequalities have reached their peak during the Belle Epoque (1880-1915) and were considerably reduced from the end of the WWI to the 1970s (Piketty, 2014). Major negotiated and not conflictual political choices, like the New Deal and the development of the welfare state in Western and Northern Europe, drove to the spectacular decrease of inequalities during this long period seeking solutions to the acute problems caused by world wars and the crisis of 1929. The creation of the European Economic Community was also a major step for a negotiated future avoiding wars and building a more inclusive future within and among participating countries and beyond.

The international political change with the rise of neoliberal ideas and policies and the collapse of state socialist regimes led to the new increase of inequalities since the late 1970s (Piketty, 2014). The unleashed development of social inequalities, developed in parallel with the redraw of the welfare state, created major problems not only in terms of social justice but also in terms of managing social development. Rising social inequalities have been increasingly considered as a barrier to a sustainable social future ([1]).

The New European Bauhaus (NEB) (COM, 2021a, b) is a major European initiative to improve the built environment and its use bringing to the fore the issue of inclusiveness, at the same level and without merging the performance of projects with sustainability and beauty issues. Each NEB project must be sustainable, beautiful and inclusive.

The Inclusiveness dimension of NEB projects refers to a twofold social objective. On the one hand, NEB projects mainly aim at increasing the equal access of the products and services they provide by diverse groups in terms of social status, citizenship, age, gender etc. and, on the other, at guaranteeing that these projects are operated in ways enhancing democratic participation, co-production and effectiveness in their management.

Within the New European Bauhaus, *diversity* and *equality* are concepts employed to address the principle that, to promote a socially fair transition — as outlined by the European Green Deal (COM, 2019) — we must address the inequalities that are related with this transition. For New European Bauhaus projects, this signifies affordable, accessible and non-discriminatory access to suitable buildings and living spaces adhering to high-quality standards, situated in neighbourhoods that uphold adequate services, promoting equal opportunities for their residents, leaving no one behind.

Building on the NEB core value of inclusiveness, NEB transformative projects promote togetherness — which refers to concepts of inclusion, diversity, equality, accessibility, and affordability — as a means to consider and remove potential barriers to access and use of the resources and opportunities offered, avoiding any form of discrimination based on individual or social groups' characteristics. At the same time, it involves responding consistently and thoughtfully to the expressed needs within the project context, particularly those of individuals who are at a higher risk of exclusion or marginalisation than others and whose needs might remain unexpressed or unrecognised.

To guide project teams in assessing the level of diversity and equality, specific targets have been set with regard to housing affordability, inclusive accessibility, neighbourhood equality. For each of these topics, the targets to be achieved are outlined with the aim of maximising the positive impacts of the project on inclusiveness/togetherness.

Governance is the political and managerial facet of 'inclusiveness'. Governance is embodied by rules and norms, and implemented through hard tools (laws, planning designs and strategies, funding schemes, etc.) and soft tools (ways of decision-making, participatory and co-production procedures, targeting, administrative capacity building, etc.) to implement NEB goals effectively and democratically.

Hard and soft governance processes embrace crucial aspects that directly or indirectly affect the design and implementation of NEB projects. The three dimensions of NEB projects (Sustainability, Beauty, and Inclusiveness) are all regulated by legislation and influenced by democratic participation and the effectiveness of public services. Hard governance processes, relate to how existing legislation, regulations, and strategic plans can enforce or encourage the design and implementation of NEB projects. Soft governance processes influence

[1] https://www.worldbank.org/en/topic/isp/overview.

the level of democratic governance (mainly clarity, consensus, participation, and co-creation) and effectiveness (administrative capacity) in the design and implementation phases of the NEB projects. Both hard and soft governance tools are related to binding legislative/regulation aspects involved with the identification and classification of available requirements, standards, and codes of practice related to the inclusiveness dimension of the New European Bauhaus.

The NEB Compass (European Commission, 2022) asserts that participatory processes "*refer to the degree to which the communities affected by the project are involved in the design, decision-making, and implementation phases*". It starts from the premise that a NEB project will always involve civil society stakeholders within a highly participatory framework and highlights the need to foster multilevel engagement and co-creation processes for the effective implementation of NEB projects.

Issues of diversity, equality and governance are regulated in different ways and at different levels across Europe and beyond. The self-assessment method is taking into account these potential contextual differences in order to focus on the assessment of the strategic choices of projects and their potential impact, rather than assessing the different and unequal contextual conditions in which the projects operate. This focus of the self-assessment method is vividly expressed by acknowledging contextual differences in most indicators related to inclusiveness.

5.2 Assessment targets to achieve

5.2.1 Diversity and equality

In societies like the European ones, characterised by market-based economic systems and high competitiveness, which have seen social protections decrease and inequalities rise in recent decades (Sayek-Böke, 2021), it becomes more urgent to combat social exclusion, marginalisation and discrimination. This effort must take place at all levels of intervention and policies, including the design and implementation of projects for buildings and living spaces.

Transformative projects aiming for the green transition must integrate the value of togetherness into their process, in line with the Cohesion Policy 2021–27 ([2]) to correct imbalances between countries and regions.

In operational terms, this means incorporating into the design and implementation of projects, the principles, values, and objectives advocated and promoted by the European Union through different policy documents and strategies, such as the New Leipzig Charter (FMI, 2020b), the Urban Agenda for EU (EU Ministers for Urban Matters, 2016), the Territorial Agenda 2030 (FMI, 2020a), the EU Pillar of Social Rights (European Commission, 2017). As encouraged in the Davos Declaration (SFoC, 2018), to aim for a Baukultur quality system, it is necessary to actively build social cohesion.

Diversity is understood as the presence of dissimilarities among individuals within a population based on their characteristics (social, economic, cultural, gender, origin, age, physical conditions, etc.), and *equality*, as the condition in which individuals occupy equidistant positions in a system (Maloutas, 2021), for example, because their access to existing resources is based on a fair and just system. Both concepts are here associated to combine two primary objectives, from the perspective of maximising the impacts of a project in terms of inclusiveness. First, to reduce the aforementioned distance between positions occupied by individuals within the context of reference. This translates, for example, into the adoption of tools and project choices that promote affordability and, consequently, access to fundamental resources — such as housing — for disadvantaged households, in neighbourhoods that offer services and a quality of life comparable to affluent ones, while simultaneously ensuring protection against exclusion and segregation. Second, to enhance the opportunities for everyone to access resources (existing or provided by the project) without being discriminated against based on their individual or group characteristics.

In this context, the NEB self-assessment method proposes a framework that establishes the need to consider, in the implementation of a project, all possible barriers to the complete and satisfactory utilisation of existing resources and opportunities by each member of the community. This includes a particular focus on individuals and groups that are more susceptible to exclusion and marginalisation and that must be identified in the project design phases to be adequately taken into account.

Relying on three fundamental qualities that an inclusive project should aspire to acquire — i.e. affordability, accessibility, and equality — as well as on the ambition of NEB to upscale a project through its capacity of

[2] https://ec.europa.eu/regional_policy/en/2021_2027/.

bringing about societal change, means that the project must incorporate these qualities at every stage, from design to implementation to monitoring and evaluation.

To guide the project team in making choices that enable them to align in the best possible way with the principle of inclusiveness, the most relevant themes for a project aspiring to be affordable, accessible, and territorially equal have been identified.

5.2.1.1 Housing affordability

In the European context, where the basic right to housing is not universally guaranteed (differently from what generally happens in other fields of welfare like education, health, social insurance), affordability is one of the dimension aspects that influences the access to that very right.

Commonly recognised in the literature as the quantitative assessment of the ability of individual households to afford adequate housing, affordability is operationalised in the NEB method not as a single indicator but across the various dimensions that collectively contribute to the right to access housing. The reasons for this choice are twofold: first, affordability indexes can hardly capture the extent of the problems to access decent housing (Sendi, 2014), because housing regimes can vary a lot in Europe and affordability indexes are not context related. Second, affordability indexes also fail to establish a robust normative approach to ensuring access to adequate housing because there is no consensus among scholars and policymakers on how to measure affordability, and thus each method has inherent shortcomings (Li, 2015). Housing affordability is historically related to the de-commodification process ensuing from the development of the welfare state, which enabled the right to housing as one of its main pillars. However, processes developed in different regimes in other parts of the world (e.g. increased salaries in the US) have also led to increased housing affordability. In line with the European context, the NEB method considers a project to be affordable if it opposes the logic of housing as a commodity and tackles the inequalities that are reproduced through access to housing.

Such an endeavour requires a comprehensive and multidimensional approach.

The most adequate territorial/administrative levels to work for housing affordability and accessibility are the supra-national, national, and regional, with a significant role to be played at the local (urban and metropolitan) scale. Much less can be achieved at the neighbourhood and building scale level. Nonetheless, through the identified target and the corresponding indicators, the NEB method assists project leaders with making choices that promote or improve housing affordability, in ways depending on the contexts where they operate. The aim of a NEB-aligned project is to change the culture of the production and management of the built environment through the aggregate impact of choices of multiple projects.

5.2.1.2 Inclusive accessibility

In scholarship, inclusive accessibility may broadly encompass concepts such as inclusion, diversity, equality, and social accessibility (Zallio and Clarkson, 2021). In the context of the NEB method, inclusive accessibility refers to every process of social inclusion that takes place in the built environment and should enable people to access services and spatial resources without being discriminated. It goes beyond the implementation of design standards for (physical) accessibility, and centres around the more invisible and intangible qualities and characteristics of places, which oftentimes determine the in/exclusion of certain groups or individuals. Social inclusion is per se a complex, multifaceted concept (United Nations, 2016), and, as such, its definition shifts and varies in documents produced by both international organisations and programmes as well as scholarly works (Leemann et al., 2022). This multidimensionality is also reflected on the fact that the concept is highly context-dependent (United Nations, 2016), and thus 'shapes' itself in multiple ways when adjusting to different places.

Choices made in the built environment are often the result of the preferences and needs of certain social groups at the expense of others, whose disadvantaged conditions lead to exclusion and marginalisation, ultimately resulting in a lack of recognition of their needs. People can be socially excluded from accessing resources and opportunities in many ways (due to social, economic, cultural, gender-related barriers, etc.) and because of discriminatory actions.

In the NEB method, an intersectional approach to social inclusion is adopted: in other words, it is considered that individuals' lives can be influenced by the combination of a multitude of discriminatory processes, linked to specific context and identities. From this perspective, each NEB project must prevent implementing forms of discrimination by basing its design choices on a deep understanding of the context and actively promoting the inclusion of individuals and groups that are more vulnerable or marginalised. This approach encourages project teams to collect disaggregated data, especially sex-disaggregated data, as suggested by the New Urban Agenda

(United Nations, 2017). The goal is to generate a comprehensive understanding and identify potential discriminatory exclusion processes.

5.2.1.3 Neighbourhood equality

Attention to the neighbourhood brings the principles of inclusion and equality to the appropriate scale (where their implementation can be experienced and perceived) and ensures the availability and access to adequate resources and opportunities for all citizens, countering any form of segregation and ensuring an optimal physical, social, and mental setting for a good quality of life.

Offering adequate and affordable access to resources and opportunities for housing, education, healthcare, transport, and leisure, is paramount to prevent segregation and ensure that urban services and amenities are evenly distributed (Arbaci, 2019). This goal must be accompanied by strategies to avoid that increased quality in neighbourhood services and attractiveness results in higher housing prices, displacement, and gentrification.

Focusing on ensuring equality in neighbourhoods, which involves inclusive access to quality services and spaces, can mitigate segregation and gentrification in two ways. Firstly, it can restrict the degree of segregation and the risk for gentrification by ensuring that all neighbourhoods are appealing, thereby minimising the impact of neighbourhood inequality. Secondly, and more significantly, it can mitigate the consequences of segregation in terms of variations in life opportunities and quality of life.

5.2.2 Governance

The *governance* component of the Inclusiveness dimension in the self-assessment method aims at evaluating by measuring the performance of NEB projects in terms of promoting the democratic imprint of participatory and co-production processes. In this way, the governance component promotes efficiently the NEB principles in all dimensions (Sustainability, Beauty, Inclusiveness) through enhanced administrative capacity and the suitable use of available legal tools and management practices and cultures.

When it comes to governance tools associated with maximising administrative capacity, participation, and multilevel co-creation processes, the NEB Compass concludes that "a *NEB project should embrace participatory principles. These principles describe the process through which a project should operate and work to achieve the highest level of ambition in the three values*" (European Commission, 2022). Moreover, the same document highlights the need to foster multilevel engagement and co-creation processes for effective implementation of the NEB projects.

Regarding hard governance tools, the NEB Compass highlights, for instance, that "*an inclusive project fosters and equalises relations between users and/or communities, safeguarding the principle of equal treatment and social justice over time. Inclusion and open access to services are enabled via structural mechanisms such as funding instruments, business models, planning, policies, regulations, and other institutionalisation processes*" (European Commission, 2022). In addition, the Davos Declaration (SFoC, 2018) suggests, for instance, that "*high-quality Baukultur fosters vibrant and mixed-use neighbourhoods. It creates built environments that embrace contemporary cultural expressions while at the same time respecting cultural heritage. It provides sustainable living conditions and strengthens social resilience by producing decent, affordable, and accessible housing*". Projects should follow the existing legislation and rules and make an extra effort when existing NEB principles are not particularly promoted in existing frameworks or are absent.

Alongside, there are two complementary and key governance issues to be considered when assessing governance within the NEB projects design, decision-making, and implementation phases. The first relates to the influence of different types of stakeholders, as well as their diversity and their representativeness of the population involved. The second relates to the level of administrative capacity to effectively implement the NEB projects. This administrative capacity is also linked to the ability of using existing regulations, legislation and strategic planning processes to promote NEB principles.

5.3 Selection criteria and list of KPIs

A key challenge in developing the self-assessment method for the dimension of Inclusiveness was the lack or limited existing work on similar evaluations and quantified and previously tested indicators. The development of indicators had to provide groundbreaking work both on the pertinence and the ways the chosen criteria could operate for the self-assessment method.

In the diversity and equality part of Inclusiveness, the three main issues that are assessed are affordability, accessibility and social cohesion at the neighbourhood level. Does the self-assessed project provide products and services at affordable prices including low-means households? Does it also provide products and services accessible to all, without discrimination based on race, gender, age, size of household etc.? Does the project promote social cohesion in its neighbourhood — through the products and services it provides — by opposing or mitigating segregation trends and gentrification processes? Eight key performance indicators (KPIs) have been selected to evaluate different aspects of these three main issues. Some of the indicators belonging to these KPIs address these issues directly: for example, one of the indicators of the KPI 'affordability' is mapping the way housing units are allocated by the project, and thus immediately evaluates their affordability; another indicator, part of the KPI 'Inclusive quality, equality and accessibility', examines whether the project provides a specific housing tenure (housing for rent) and, in this way, provides evidence about the project contribution to providing affordable housing through access to the most accessible and most affordable tenure to low-means households.

In the governance part of inclusiveness, the two main issues selected for the self-assessment method are the participatory processes embraced by the projects and the capacity of managing teams to design and implement NEB projects. The main governance issue that is evaluated by the self-assessment method is the use and the extent of use of participatory procedures in the design and implementation of projects. The emphasis on this issue is not only based on the preference of democratic versus top-down management procedures, but also on the prevalence of the former in terms of the enriched contribution of multiple stakeholders and the building of consensus for a common outcome through the participatory procedure.

The preliminary step for the evaluation of a project with respect to the targets of affordability, social accessibility, and neighbourhood equality, is a characterisation of the context. Many facets of a project must be contextualised for accurate assessment, ensuring that projects are neither penalised nor rewarded based on specific local circumstances, which may vary in terms of inclusiveness. A contextual assessment that tries to flatten these background differences so that each project can be evaluated against its background and not in absolute terms is then considered as key to build a more accurate and more just evaluation system. The characterisation of the context is designed according to each indicator rationale and in line with the overall targets, as expressed by KPIs.

The Inclusiveness indicator scores are based on an aggregation of metric scores, where metrics are typically in the form of questions to the user. Metric scores are based either on a vector scale or, when combined with contextual questions, on a matrix scale. This enables project teams to ascertain whether the decisions made for each indicator (and eventually target) are leading them closer to or farther away from the criteria related to NEB principles. Overall, a comprehensive evaluation approach has been embraced, wherein each of the three dimensions is perceived both as an outcome of project decisions and assessed in connection with the context.

The KPI score is obtained as a weighted average of indicator scores (Section 2.2.2). The **key performance indicators** within the Inclusiveness dimension together with the associated indicators and indicator weights ($w_{I,i,j}$) are provided in Table 155. Although minimum KPI scores are not prescribed in the NEB self-assessment method, it is highly recommended that all KPIs reach the Acceptable performance class. The same table also presents the field of application and consideration of indicators according to the project classification based on spatial scale, type, main use and relevance to cultural heritage.

Table 155. Key performance indicators (KPIs) within Inclusiveness.

KPI[1]	**Weight ($w_{I,i}$)**	**Indicator**	**Scale**	**Type**	**Main use**	**Cultural heritage**[2]	**Weight ($w_{I,i,j}$)**
Funding and land value (I.1)	0.08	Main funding channels (I.1.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential	Not affected	0.6
		Purpose of the land (I.1.2)	Building/ Neighbourhood/ Urban	Newbuild	Residential	Not affected	0.4
Affordability (I.2)	0.16	Criteria for allocation of housing units (I.2.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential	Not affected	0.35
		De-commodification of the housing stock (I.2.2)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential	Not affected	0.25
		Affordable adoption of high-quality	Building[3]/ Neighbourhood[3]/	Newbuild/ Renovation	Residential	Not affected	0.2

		housing conditions (I.2.3)	Urban[3]				
		Affordable access to services and amenities (I.2.4)	Building/ Neighbourhood/ Urban[4]	Newbuild/ Renovation	Non-residential	Not affected	0.2
Inclusive quality, equality and accessibility (I.3)	0.16	Available dwelling space for households (I.3.1)	Building[3]/ Neighbourhood[3]/ Urban[3]	Newbuild/ Renovation	Residential	Not affected	0.2
		Maintaining the quality of spaces and services (I.3.2)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.2
		Rental scheme (I.3.3)	Building[3]/ Neighbourhood[3]/ Urban[3]	Newbuild/ Renovation	Residential[5]	Not affected	0.15
		Homeownership scheme (I.3.4)	Building[3]/ Neighbourhood[3]/ Urban[3]	Newbuild/ Renovation	Residential[5]	Not affected	0.15
		Pedestrian accessibility to essential services and amenities (I.3.5)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential	Not affected	0.1
		Accessibility to services and amenities by public transport (I.3.6)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential	Not affected	0.1
		Pedestrian accessibility to public transport (I.3.7)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.1
Rent regulation (I.4)	0.08	Rental contracts (I.4.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential[5]	Not affected	0.35
		Rents setting (I.4.2)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential[5]	Not affected	0.65
Impacts on neighbourhood social cohesion (I.5)	0.10	Housing typology mix (I.5.1)	Neighbourhood/ Urban[4]	Newbuild/ Renovation	Residential	Not affected	0.3
		Prevention of segregation at the micro-scale (I.5.2)	Building[5]/ Neighbourhood[5]	Newbuild/ Renovation	Residential	Not affected	0.2
		Prevention of gentrification and displacement (I.5.3)	Neighbourhood[5]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
		Outreach activities for project-related social and cultural services (I.5.4)	Building/ Neighbourhood	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.2
Needs and resources for social accessibility (I.6)	0.13	Active accessibility needs in the project strategy (I.6.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.25
		Mapping of assets and resources (I.6.2)	Building/ Neighbourhood/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.4
		Diversification of activities in response to local needs (I.6.3)	Building/ Neighbourhood	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.35
Needs of vulnerable and	0.13	Acknowledgement of cultural and social	Building/ Neighbourhood/	Newbuild/ Renovation	Residential/	Not affected	0.4

marginalised groups (I.7)		barriers to accessibility (I.7.1)	Urban		Non-residential		
		Local support networks and trained social workers (I.7.2)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
		Needs of vulnerable and marginalised groups covered by activities (I.7.3)	Building/ Neighbourhood	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.3
Anti-discrimination initiatives (I.8)	0.08	Anti-discriminatory action (I.8.1)	Building/ Neighbourhood	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.65
		Monitoring plan of safety and non-discrimination conditions (I.8.2)	Building/ Neighbourhood/ Urban[4]	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.35
Involvement of stakeholders (I.9)	0.08	Involvement of local stakeholders in project meetings (I.9.1)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.18
		Involvement of public and private sector stakeholders in project meetings (I.9.2)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.1
		Contribution of local civil society stakeholders to project design (I.9.3)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.2
		Contribution of public and private sector stakeholders to project design (I.9.4)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.1
		Diversity and representativeness of the stakeholders in project design (I.9.5)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.12
		Contribution of stakeholders from vulnerable groups to project design (I.9.6)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.18
		Project budget allocated to engagement events (I.9.7)	Building/ Neighbourhood/ Urban	Newbuild/ Renovation	Residential/ Non-residential	Not affected	0.12

1 Although minimum KPI scores are not prescribed in the NEB self-assessment method, it is highly recommended that all KPIs reach the Acceptable performance class.

2 Yes: Indicator applicable only to cultural heritage; No: Indicator non-applicable to cultural heritage; Not affected: Indicator applicable irrespective of cultural heritage.

3 The assessment should focus on representative housing types within the building, neighbourhood or urban scale project. The user may assess a housing type that can represent on average the different attributes (or integrates the most dominant ones) within the project. Alternatively, the user may perform multiple assessments corresponding to distinct housing types, representative of the building stock. In the latter case, the indicator score is estimated as a weighted average, with weights obtained from the relative occurrence of each housing type (in terms of number of housing units, area, or other features).

4 The user should assess separately the neighbourhoods within the urban scale of the project. The indicator score is estimated as a weighted average, with weights based on neighbourhood features (e.g. population, income).

5 Additional conditions apply.

Source: JRC.

The **KPI performance class scores** (PCS) assigned to all KPIs of the Inclusiveness dimension, as a function of the attained KPI performance class and KPI score (Section 2.2.3) are provided in Figure 102.

Figure 102. KPI performance class scores (PCS) in the Inclusiveness dimension.

Performance class:	Low	Acceptable	Good	Excellent
KPI performance class score (PCS):	10	45	75	100

Source: JRC.

The Inclusiveness **dimension score** (I) (Section 2.2.4) is evaluated according to Equation (240), as a weighted average of KPI performance class scores. The number of the considered KPIs (*m*) within the equation depends mainly on the project classification according to spatial scale, type and main use (Table 155). On a few occasions, an indicator may be omitted depending on projects aspects that are not related (only) to the project scale, type and main use (Sections 5.4–5.12). The KPI weights ($w_{I,i}$) are reported in Table 155.

$$I = \sum_{i=1}^{m} (w_{I.i} \cdot PCS_{I.i}) \Big/ \sum_{i=1}^{m} (w_{I.i}) \quad (240)$$

Weights in the above process, for both indicators and KPIs, are based on expert judgement in the Inclusiveness dimension, considering the comparative value of the content of indicators and KPIs.

The Inclusiveness **dimension performance class** is assessed considering the dimension score and dimension thresholds according to Figure 103.

Figure 103. Inclusiveness performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
Inclusiveness dimension thresholds (t_I):	0 ≤		$t_{I, Acceptable}$ ≥ 40		$t_{I, Good}$ ≥ 60		$t_{I, Excellent}$ ≥ 80		≤ 100

Source: JRC.

With some exceptions, Inclusiveness indicators, and thus KPIs, are designed to be applicable at all spatial scales, from the building to the neighbourhood and the urban scale. More than half of the indicators apply to both project main uses, i.e. residential and non-residential use. Two KPIs (i.e. I.1 and I.4) and component indicators in other KPIs are intended for residential use only. Regarding the project type, indicator I.1.2 applies only to newbuilds, but the remaining indicators apply to both types. Lastly, in the case of the Inclusiveness dimension, all KPIs can be applied to cultural heritage projects addressing buildings and living spaces.

In Sections 5.4–5.12, the key performance indicators in the Inclusiveness dimension are presented along with their calculation based on associated indicators. For each indicator, the following info is provided: (*i*) a brief description, (*ii*) the component metrics and sub-metrics (Section 2.2.1) typically in the form of questions, and (*iii*) the evaluation of the indicator score as a function of metric scores, always within a range of 0–100. Indicator thresholds used to link indicator scores with performance classes are also provided. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

5.4 Funding and land value (I.1)

5.4.1 Description and assessment

The funding channels of a project and the value derived from land transformation play a crucial role in directing the built environment to avoid or mitigate inequalities and pursue the public interest. Projects aimed at facilitating the creation of financial assets rather than offering public goods, through either the use of financial and speculative financing circuits or by harnessing land value appreciation for speculative purposes, may result in price increases and uneven development (Aalbers, 2019). This process can have even more serious consequences for the affordability of housing access, primarily because it contributes to price inflation and drives cycles of price rises (United Nations, 2019). In this respect, the de-commodification process, which involves excluding land from speculative markets, is crucial to restore their use value, prevent uncontrollable price hikes, and address social claims.

This target will be more easily achieved in national and regional contexts where non-financial circuits and funding instruments exist, and where financial and land markets are highly regulated. Nevertheless, depending on the project targets, some measures can be taken at the project level with the ambition to limit the use of financial and speculative channels that fund the project development and to de-commodify land, whenever possible.

Such measures include:

— Regulating the speculative effect of the financial activity to the minimum extent possible in each context, and privileging non-financial, non-speculative financing circuits.

— Ensuring that land is allotted based on use value (de-commodification).

— Ensuring that the surplus created by altering the use of land use (e.g. by increasing the number of building permits) is either acquired by public institutions through land taxes to provide public goods (such as social housing), or transformed into affordability improvements through housing price or rent reduction.

Although linking with national (or, in some instances regional and supra-national) regulatory frameworks, the target is framed at the project level, that is, it can be evaluated and monitored at this scale. At the same time, existing regulatory frameworks directly influence the viability of the target.

Under the KPI Funding and land value (I.1), an assessment of the following indicators is performed:

— *Main funding channels (I.1.1)*

— *Purpose of the land (I.1.2)*

In the **general case**, when all indicators are considered, I.1 score is evaluated according to Equation (241).

$$I.1 = \sum_{j=1}^{2}\left(w_{I.1.j} \cdot I.1.j\right) \Big/ \sum_{j=1}^{2}\left(w_{I.1.j}\right) = 0.6 \cdot I.1.1 + 0.4 \cdot I.1.2 \leq 100 \qquad (241)$$

Indicator I.1.2 does not apply to **renovation projects**, therefore it is excluded from the calculation of I.1 in such projects, resulting in:

$$I.1 = \sum_{j=1}^{2}\left(w_{I.1.j} \cdot I.1.j\right) \Big/ \sum_{j=1}^{2}\left(w_{I.1.j}\right) = 0.6 \cdot I.1.1/0.6 = I.1.1 \leq 100 \qquad (242)$$

Each indicator is evaluated with a score between 0-100. The performance class of the I.1 key performance indicator is assessed according to the thresholds in Figure 104.

Figure 104. I.1 performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.1 thresholds ($t_{I.1}$):	0 ≤		$t_{I.1, Acceptable}$ ≥ 40		$t_{I.1, Good}$ ≥ 60		$t_{I.1, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.4.2 Main funding channels (I.1.1)

Indicator I.1.1 applies only to **residential projects**.

To orientate projects towards the values of inclusion, social cohesion, and public interest, it is necessary to reduce reliance on speculative forms of built environment production, through which the enhancement of private investments is prioritised rather than the common good.

A project that serves the public good (hence, serves inclusiveness) should reduce the participation of financial intermediaries to the minimum extent made possible in each context and favour non-financial, non-speculative financial circuits, to prevent the growth of spatial inequalities.

Financial circuits can be understood as "*the sociotechnical systems that channel investments in the form of equity and debt into urban production*" (Halbert and Attuyer, 2016). Examples of financial channels include bank mortgages, investments banks, direct investments by financial (e.g. non-bank, private equity, hedge funds) actors, etc. Examples of non-financial channels include state grants, mortgages by public or not-for-profit agencies, revolving funds, circuits of household or worker savings, etc.

Funding channels must be assessed with respect to the existing financial system. A deregulated financial system represents a higher risk for equity in the built environment production.

The assessment requires the following information to be identified and collected:

— Standards, guidelines and regulatory frameworks relevant to the housing market in context,

— Financial schemes adopted by the project.

The indicator is evaluated according to the questions and the score matrix provided in Table 156.

Table 156. I.1.1 score.

Contextual variance: *In the context of the project, how is the housing financial system regulated? (single selection allowed)*					
a. Fairly or highly regulated (e.g. fit-for-purpose financial policies, regulation of mortgage lending, regulated financial institutions, regulated access to housing markets). b. Poorly or not regulated (e.g. deregulated housing finance system, deregulated use of financial products related to housing finance, deregulated access to housing markets).					
Metric: *What are the main funding channels for the project? (single selection allowed)*					
1. The project is mainly funded through financial (for profit) channels with no added regulations. 2. The project is mainly funded through financial (for profit) channels with regulations against speculative investments. 3. The project is funded through a mix of financial and non-financial channels with no added regulations 4. The project is funded through a mix of financial and non-financial channels with regulations against speculative investments. 5. The project is mainly funded through non-financial funding					
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
[a]	10	30	50	70	90
[b]	20	50	70	90	100

Source: JRC.

Figure 105 shows the indicator thresholds used to link indicator scores with performance classes for I.1.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 105. I.1.1 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
I.1.1 thresholds ($t_{I.1.1}$):	0 ≤	$t_{I.1.1, Acceptable}$ ≥ 40	$t_{I.1.1, Good}$ ≥ 60	$t_{I.1.1, Excellent}$ ≥ 80 ≤ 100

Source: JRC.

5.4.3 Purpose of the land (I.1.2)

Indicator I.1.2 applies only to **newbuild residential projects**.

Keeping land outside the market and the financial system is the most efficient way to regulate the development of the built environment towards affordability and/or common good. This means that the economic value derived from the development of a project on a piece of land must be reinvested outside speculative mechanisms and in support of a public purpose (public services, affordable housing, welfare policies).

Various tools may exist at the national, regional, or local levels (e.g. land value taxation or recapture, direct provision of public land, land use planning). It is necessary to assess whether the project, with or without an increase in land value (depending on whether the land is de-commodified or not), invests in public goods or in the enhancement of private profit.

The assessment requires the information about land ownership and occupancy rights to be identified and collected.

The indicator is evaluated according to the questions and the score matrix provided in Table 157.

Table 157. I.1.2 score.

Contextual variance: *In the context of the project, to what extent land is de-commodified? (single selection allowed)*							
a. Land is the private property of the developer or subsequent property owners (residents or landlords) (answers 1–4 allowed in the following metric). b. Land is de-commodified — either owned by a public or not-for-profit organisation or ownership of a co-op or other collective organisations — but no guarantees on its future status exist (answers 5–7 allowed in the following metric). c. Land is de-commodified, and this status is guaranteed in the long term through ad hoc legal mechanisms (e.g. community land trusts) (answers 5–7 allowed in the following metric).							
Metric: *What purpose is the land developed for? (single selection allowed)*							
1. There is increase in land value, and this increase is reinvested entirely into housing price or rent reduction, affordable housing, or public purpose. 2. There is increase in land value, and this increase is mostly (>50%) reinvested into housing price or rent reduction, affordable housing or public purpose, and partially for profit. 3. There is increase in land value, and this increase is limitedly reinvested into housing price or rent reduction, affordable housing or public purpose. 4. There is increase in land value, and this increase is fully reinvested according to market rules. 5. There is no increase in land value, and this economic advantage is entirely used for the benefit of the developers/funders. 6. There is no increase in land value, and this economic advantage is partly used for the benefit of the developers, funders, and partly as land taxes, housing price/rent reduction or public purpose. 7. There is no increase in land value, and this economic advantage is entirely used as land taxes, housing price reduction or public purpose.							
Indicator score[1]	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**	**[7]**
[a]	100	65	35	0	—	—	—
[b]	—	—	—	—	0	30	100
[c]	—	—	—	—	0	50	100

[1] Dashes correspond to options that cannot be selected by the user, given the contextual variance.

Source: JRC.

Figure 106 shows the indicator thresholds used to link indicator scores with performance classes for I.1.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 106. I.1.2 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
I.1.2 thresholds ($t_{I.1.2}$):	$0 \leq$	$t_{I.1.2, Acceptable} \geq 40$	$t_{I.1.2, Good} \geq 60$	$t_{I.1.2, Excellent} \geq 80$	≤ 100

Source: JRC.

5.4.4 Example (I.1)

A project involves the construction of a new senior residence for vulnerable individuals on publicly owned land. The project is classified as: Building – Newbuild – Residential.

The project is fully funded through public channels, i.e. partly from municipal funds and partly from a European grant. The context is characterised by a poorly regulated (liberalised) financial system. The above result in a [b-5] response in Table 156, thus in I.1.1 = 100.

The publicly owned land does not yield an increase in value and is used for public purposes, thus remaining completely outside the market system, promoting the public interest. Considering a [c-7] response, I.1.2 = 100.

According to (242), the indicator score is evaluated as I.1 = 100, corresponding to an Excellent performance class, and a performance class score equal to $PCS_{I.1}$ = 100.

5.5 Affordability (I.2)

5.5.1 Description and assessment

The European context is characterised by a great diversity of features in housing regimes and policies across and within states (Opinion, 2018). As a result of the crucial role played by the regulatory and policy frameworks, guaranteeing affordability at the project level might be a radically different endeavour in different contexts. Where housing regimes are orientated towards the right to housing (with the existence of, e.g. non-speculative financing circuits, robust protections for tenants, large public housing stocks), providing housing that is affordable vis-à-vis existing needs is much easier than in systems where housing welfare is residual. For this reason, affordability needs to be assessed in relation to the context where the project is implemented, to avoid rewarding or penalising projects for their national/regional/local housing regimes. To this end, indicators have been conceptualised and operationalised to measure the extent to which the project can promote/improve affordability within the context of its specific housing regime and/or to the prevailing economic status of the area where the project is being developed.

Affordability is promoted by the project if:

— in the case of housing projects, housing units (i.e. dwellings) are assigned by following social/public housing criteria (for the entire or at least a considerable part of the building stock).

— buildings and spaces are and will remain out of the speculative market over the long term.

— in the case of housing projects, any improvement of the housing standards, including for energy efficiency, does not result in a price increase that could harm or displace the most vulnerable families, leading to unaffordability in housing.

— it takes into account the purchasing power of residents or service users in providing services that are affordable and accessible to all.

Under the KPI Affordability (I.2), an assessment of the following indicators is performed:

— *Criteria for allocation of housing units* (I.2.1)

— *De-commodification of the housing stock* (I.2.2)

— *Affordable adoption of high-quality housing conditions* (I.2.3)

— *Affordable access to services and amenities* (I.2.4)

Three out of the four indicators that form KPI I.2 apply only to residential projects, i.e., those that include housing units (i.e. I.2.1, I.2.2 and I.2.3), whereas the fourth applies only to non-residential projects. Accordingly, I.2 score for **residential projects** is evaluated according to Equation (243).

$$I.2 = \sum_{j=1}^{4}\left(w_{I.2.j} \cdot I.2.j\right) \Big/ \sum_{j=1}^{4}\left(w_{I.2.j}\right) = \frac{(0.35 \cdot I.2.1 + 0.25 \cdot I.2.2 + 0.2 \cdot I.2.3)}{(0.35 + 0.25 + 0.2)} \leq 100 \tag{243}$$

I.2 score for **non-residential projects** is evaluated according to Equation (244).

$$I.2 = \sum_{j=1}^{4}\left(w_{I.2.j} \cdot I.2.j\right) \Big/ \sum_{j=1}^{4}\left(w_{I.2.j}\right) = (0.2 \cdot I.2.4)/(0.2) = I.2.4 \leq 100 \tag{244}$$

Each indicator is evaluated with a score between 0-100. The performance class of the I.2 key performance indicator is assessed according to the thresholds in Figure 107.

Figure 107. I.2 performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
I.2 thresholds ($t_{I.2}$):	0 ≤	$t_{I.2, Acceptable}$ ≥ 40	$t_{I.2, Good}$ ≥ 60	$t_{I.2, Excellent}$ ≥ 80	≤ 100

Source: JRC.

5.5.2 Criteria for allocation of housing units (I.2.1)

Indicator I.2.1 applies only to **residential projects**.

Creating large stocks of public, social, and non-profit affordable housing is the most effective way to promote affordability, i.e. by removing housing from the market dynamics. This stock directly provides housing solutions for those most in need, and indirectly affects market dynamics towards affordability through its impact on housing supply and demand. These de-commodified housing stocks are also the most practical solution to address the conflict between the goal of providing universal housing welfare and prioritising households in need. As suggested by the Housing Partnership for the EU Urban Agenda (2018), the production of affordable housing can involve either the provision of new housing or the modernisation of existing ones. In both cases, achieving affordability requires protecting both tenants and homeowners, particularly the most vulnerable, from market failures and speculative dynamics. While this effort needs support from national and local policies, the project itself can and should aim to promote affordability as much as possible. This can be done by allocating housing units according to criteria that protect the owner or the tenant, offering prices or rents that are below market rates and accessible to the most vulnerable households.

To contribute to the right to housing, a project should address the needs for affordable housing that are present in its context, thereby promoting or improving housing affordability overall. The indicator can be evaluated at any spatial scale by comparing the project housing supply to the various housing needs at the neighbourhood, urban, regional, or even national level. However, for the purpose of the NEB self-assessment tool, it is reasonable to consider housing needs at the urban level for building and neighbourhood-scale projects, or at a more extended regional level for urban-scale projects. Accordingly (Table 158), the context in which the project develops (contextual variance) is always assessed at a higher spatial level than the project scale, i.e. urban level for building and neighbourhood-scale projects, or regional level for urban-scale projects. On the other hand, the (single) metric of the indicator refers to the project scale.

The assessment requires the following information to be identified and collected:

- Information about the local housing system and the share of public and not-for-profit housing.
- Project strategy for the allocation of housing units.

According to Table 158, the maximum score is assigned to projects that reach the best conditions of affordability, in a context with poor housing welfare. On the other hand, the minimum score is given to projects that despite operating within an enabling housing regime, they do not promote affordability.

Table 158. I.2.1 score.

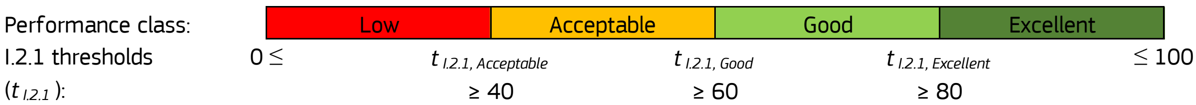
Contextual variance: *Typology of the housing system in context[1]: (single selection allowed)*					
a. Extensive public or not-for-profit sector involvement in housing provision and regulation (concerning more than 20% of the housing stock).					
b. Mix of public and private involvement in the housing sector (between 10% and 20% of the housing stock is provided by public or not-for-profit entities).					
c. Limited or absent public and social housing provision; housing predominantly allocated by market price (less than 10% of the housing stock is provided by public or not-for-profit entities).					
Metric: *According to which criteria are housing units allocated by the project? (single selection allowed)*					
1. All units are allocated by market criteria. 2. Most units are allocated by market criteria (over 55%). 3. Equal mix of units allocated by market and affordable criteria. 4. Most units are allocated by affordable criteria (over 55%). 5. All units are allocated by affordable criteria.					
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
[a]	0	15	45	70	90
[b]	10	30	55	75	95
[c]	25	45	70	90	100

[1] Urban context should be considered for building and neighbourhood-scale projects, and regional context for urban-scale projects.

Source: JRC.

Figure 108 shows the indicator thresholds used to link indicator scores with performance classes for I.2.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 108. I.2.1 indicative performance classes and thresholds.



Source: JRC.

5.5.3 De-commodification of the building stock (I.2.2)

Indicator I.2.2 applies only to **residential projects**.

The project is encouraged to create de-commodified housing to the greater extent possible, promote long-term affordability that ensures the pursuit of the public interest and security of tenure.

Also, the project should identify measures and strategies to ensure that housing cannot be re-commodified in the medium to the long term.

In practice, housing units are considered de-commodified when they are:

- owned by the public sector (government, public entities),
- owned by community and tenant members (e.g. cooperatives, community land trusts),
- owned by not-for-profit entities (e.g. foundations, social/affordable housing providers),
- bound to remain off-market in the long term, regardless of the type of ownership.

The assessment requires the following information to be identified and collected:

- Information about the local housing sector and the share of public and not-for-profit housing.
- Project strategy for the allocation of housing units.

The indicator is evaluated according to the questions and the score matrix provided in Table 159.

Table 159. I.2.2 score.

Contextual variance: *Typologies of the housing system in context[1]: (single selection allowed)*

a. Extensive public or not-for-profit sector involvement in housing provision and regulation (concerning more than 20% of the housing stock).

b. Mix of public and private involvement in the housing sector (between 10% and 20% of the housing stock is provided by public or not-for-profit entities).

c. Limited or absent public and social housing provision; housing predominantly allocated by market price (less than 10% of the housing stock is provided by public or not-for-profit entities).

Metric: *To what extent does the project promote the de-commodification of the building stock? (single selection allowed)*

1. All units can be sold to the market without restrictions.
2. All units can be sold to the market after a defined period (e.g. 5 years).
3. Most units or at least half of the units are de-commodified.
4. All units are de-commodified.
5. All units are and will remain indefinitely de-commodified.

Indicator score	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
[a]	0	20	45	70	85
[b]	0	25	50	75	90
[c]	0	30	55	85	100

[1] Urban context should be considered for building and neighbourhood-scale projects, and regional context for urban-scale projects.

Source: JRC.

Figure 109 shows the indicator thresholds used to link indicator scores with performance classes for I.2.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 109. I.2.2 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent	
I.2.2 thresholds ($t_{I.2.2}$):	$0 \leq$		$t_{I.2.2,\ Acceptable} \geq 40$	$t_{I.2.2,\ Good} \geq 60$	$t_{I.2.2,\ Excellent} \geq 80$	≤ 100

Source: JRC.

5.5.4 Affordable adoption of high-quality housing conditions (I.2.3)

Indicator I.2.3 applies only to **residential projects**.

Projects aiming for high standards, whether in the case of new housing or renovation, can end up generating negative impacts on housing prices and rents (FEANTSA, 2022).

To ensure affordability alongside high-quality conditions, the cost of access to housing should not increase, or any increase should be kept minimal, whereas retrofitting works should be agreed upon with tenants. For example, it should be considered that residents afflicted by energy poverty are unlikely to offset the increased rent cost with savings (Berger and Höltl, 2019).

In many European countries, funding schemes and grants are provided to ensure that the improvements made do not come at the expense of affordability and security of tenure, by taming the rise of housing costs (UNECE, 2021). These schemes must be linked to rent-cap guarantees or rent regulations. In cases where such funds do not exist to enforce price containment, projects that plan to absorb the costs of improving housing conditions (for example, related to energy-efficiency works) without burdening current or future residents are additionally rewarded.

Living in adequate housing is considered essential for ensuring a good quality of life. According to Eurofound (2024), the three major issues encountered are poor energy efficiency, lack of space in homes (especially for those living in apartments), and noise. The ability to adequately heat the home and having sufficient space for the household are particularly crucial aspects to pursue because they tend to be associated with disadvantaged socioeconomic conditions. To this, safety-related aspects that may require housing retrofitting, such as seismic upgrades and adjustments for accessibility barriers, are also added as components of the indicator evaluation.

In summary, for indicator I.2.3, the following main aspects are considered relevant in the evaluation of housing quality:

— Energy efficiency (see also S.1 and S.2).
— Dimensions of habitable space and rooms (see also I.3.1).
— Accessibility for the disabled (see also B.5).
— Daylight (see also B.4.2).
— Protection from hazards (see also B.3).
— Noise levels (e.g. from traffic, neighbours) (see also B.4.1).

The possible price increase related to the adoption of high-quality housing conditions should be compared:

— for renovation projects, to the cost of housing price or rent prior to the intervention.
— for new developments, to the average cost of housing price or rent at the neighbourhood level if the project is classified into the building scale, at the urban level if the project is classified into the neighbourhood scale, and at the regional level if the project is classified into the urban scale.

The assessment of the indicator should focus on representative housing types within a building, neighbourhood or urban-scale project, e.g. based on type of tenure (homeownership or rental) and allocation criteria (market or affordable). The user may assess the most dominant housing type within the project. Alternatively, the user may perform multiple assessments corresponding to distinct housing types, representative of the building stock (e.g. homeownership and market; homeownership and affordable; rental and market; rental and affordable). In the latter case, the indicator score is estimated as a weighted average, with the weights obtained from the relative occurrence of each housing type (in terms of number of housing units, area, or other features).

The assessment requires the following information to be identified and collected:

— Project design plans.
— Standards, guidelines and national standards relevant to housing quality, safety and accessibility.
— Expected or actual thermal performance.
— Information about the household composition.
— Information of sources of noise inside and outside the housing building.
— The increase in price or rent after the project development.

The indicator is evaluated according to the questions and the score matrix provided in Table 160.

Table 160. I.2.3 score.

Contextual variance: *Does the project benefit from financial support to offset the costs of adopting high-quality housing conditions (e.g. in energy efficiency or other)? (single selection allowed)*				
a. Yes b. No				
Metric: *Is the outcome of adopting high-quality housing conditions affordable? (single selection allowed)*				
1. A substantial increase[1] (≥ 10%) in price or rent results from adopting high-quality housing conditions. 2. A moderate increase[1] (≥ 3% and < 10%) in price or rent results from adopting high-quality housing conditions. 3. A small increase[1] (< 3%) in price or rent results from adopting high-quality housing conditions. 4. Prices or rents are not increased[1] due to adopting high-quality housing conditions.				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
[a]	0	30	50	90
[b]	0	50	70	100

[1] The estimation of price increase depends on the project scale and type (see Section 5.5.4).

Source: JRC.

Figure 110 shows the indicator thresholds used to link indicator scores with performance classes for I.2.3. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 110. I.2.3 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.2.3 thresholds ($t_{I.2.3}$):	0 ≤		$t_{I.2.3,\ Acceptable}$ ≥ 40		$t_{I.2.3,\ Good}$ ≥ 60		$t_{I.2.3,\ Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.5.5 Affordable access to services and amenities (I.2.4)

Indicator I.2.4 applies only to **non-residential projects**.

A project may involve the provision of services either at building scale (e.g. a building intended solely for services, or a building with mixed residential and non-residential use) or at the neighbourhood/urban scale (e.g. mixed development with residential and non-residential/service functions). In the cases of mixed use (regardless of scale) the user will need to classify the project based on the most dominant use (residential or non-residential). Alternatively, the user may opt to assess the project as two individual projects, one addressing residential use, and one addressing non-residential use, both assessed at the scale of the complete project (Section 2.3.2). Therefore, indicator I.2.4 assesses for non-residential projects the extent to which the provided services address local needs and are available to everyone, including users who are economically disadvantaged (e.g. refugees, newly arrived immigrants, single-parent households, unemployed individuals).

Services can refer to any type of facilities and activities open to the public. Activities may include courses, cultural events, festivals, meetings, collective meals, parties and workshops for children and adolescents, games, sport competitions, readings, open-air cinema, etc. Facilities may include shops, cafés, restaurants, groceries, supermarkets, community centres, sport halls, libraries, etc.

The affordability of services should be measured against local needs and purchasing power, which depends on local average income, socioeconomic conditions, but also on individuals' willingness to pay for that specific service. If the project team does not have direct access to this knowledge about the context, it is recommended that information is collected from local grassroots organisations, existing services or businesses. In the case of newbuild projects, affordability should be estimated based on expected households' socioeconomic conditions.

For building scale and neighbourhood scale projects, socioeconomic conditions should be assessed in the neighbourhood where the project will be developed. In the case of urban scale projects with significant variations in the socioeconomic profiles of the included neighbourhoods, the assessment of the indicator should be performed separately for each neighbourhood. The indicator score is finally estimated as a weighted average, with weights based on neighbourhood population.

In terms of socioeconomic conditions, neighbourhoods within their urban environment, are characterised as:

"High and middle-to-high income" with average income or average housing price/rent in the neighbourhood higher than 120% of the average values in the urban area. Such neighbourhoods are characterised by an overrepresentation of households with middle to high incomes compared to the urban (or regional) average, with a high incidence of high-level professional categories such as managers and professionals. They are further characterised by an underrepresentation of individuals and families with low incomes, belonging to modest professional categories such as routine (unskilled) workers, industrial and construction workers.

"Low and low-to-middle income" with average income or average housing price/rent in the neighbourhood lower than 80% of the average values in the urban area. Such neighbourhoods are characterised by an overrepresentation of households with low to middle incomes compared to the urban (or regional) average, belonging to modest professional categories such as routine (unskilled) workers, industrial and construction workers and of individuals working in precarious conditions or unemployed. They are further characterised by an underrepresentation of households with middle to high incomes and high-level professional categories such as managers and professionals.

"Mixed" with average income or average housing price/rent in the neighbourhood within the range of 80–120% of the average values in the urban area. Such neighbourhoods are characterised by a mix of households belonging to different socioeconomic groups, which usually combine social mix with the overrepresentation of

intermediate occupational categories such as technicians, office employees, sellers and skilled workers, and with an average income level close to the urban average.

The assessment requires the following information to be identified and collected:

- The average household income (or a proxy like average housing price/rent) at the neighbourhood and urban (or regional) level. This information is needed to define affordability at the project level.
- Information about the socioeconomic features of the wider area where the project is developed (neighbourhood, urban or regional area).
- Information about the commercial and economic strategy of planned services.

The indicator is evaluated according to the questions and the score matrix provided in Table 161.

Table 161. I.2.4 score.

Contextual variance: *In the context of the project, how can the neighbourhood be classified based on the prevailing economic status of local households? (single selection allowed)*					
a. High and middle-to-high income. b. Mixed. c. Low and low-to-middle income.					
Metric: *Does the project ensure an affordable access to services and amenities? (single selection allowed)*					
1. Less than 20% of the provided services are accessible for free or at an affordable cost for all. 2. At least 20% but less than 50% of the provided services are accessible for free or at an affordable cost for all, but their provision in the long term cannot be guaranteed. 3. At least 50% of the provided services are accessible for free or at an affordable cost for all, but their provision in the long term cannot be guaranteed. 4. At least 20% but less than 50% of the provided services are (and will be) accessible for free or at an affordable cost for all. 5. At least 50% of the services provided services are (and will be) accessible for free or at an affordable cost for all.					
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
[a]	0	30	55	70	85
[b]	0	20	45	75	90
[c]	0	10	30	85	100

Source: JRC.

Figure 111 shows the indicator thresholds used to link indicator scores with performance classes for I.2.4. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 111. I.2.4 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
I.2.4 thresholds ($t_{I.2.4}$):	$0 \leq$	$t_{I.2.4,\ Acceptable} \geq 40$	$t_{I.2.4,\ Good} \geq 60$	$t_{I.2.4,\ Excellent} \geq 80$; ≤ 100

Source: JRC.

5.5.6 Example (I.2)

A project involves the retrofitting of two buildings of social housing owned by a social housing provider, with common and commercial spaces at the ground floor. In the region where the project is taking place, approximately 8% of housing units are either publicly owned or owned by non-profit organisations, with private ownership being the dominant form of tenure. The retrofitting of the two housing buildings includes energy efficiency improvements to the properties, an increased supply of larger housing units for large families, and a general improvement in housing conditions compared to the pre-existing situation and the existing quality within the municipality.

Since the neighbourhood scale project includes mixed use, the user will need to classify the project based on the most dominant aspect and assess only this one at the scale of the complete project. Alternatively, the user may opt to assess the project as two individual projects, one addressing residential use, and one addressing non-residential use (commercial spaces), both assessed at the scale of the complete project as follows:

Project classification – a: Neighbourhood – Renovation – Residential

Project classification – b: Neighbourhood – Renovation – Non-residential

The second approach is followed in the following.

Criteria for allocation of housing units (I.2.1): The project is developed in a context where the housing system moderately involves public or non-profit entities. As a social provider is involved, all housing units are allocated based on affordability criteria. Considering a [c-5] response in Table 158, the indicator achieves a score of I.2.1a = 100 (corresponding to an Excellent performance class for this indicator). I.2.1 is omitted from the assessment of the non-residential use.

De-commodification of the housing stock (I.2.2): The two residential buildings are owned by a social housing provider and will remain so. In a region where a minimal portion of the property stock is publicly owned (response c-3 in Table 159), the indicator achieves a score of I.2.2a = 100 (corresponding to an Excellent performance class for this indicator). I.2.2 is omitted from the assessment of the non-residential use.

Affordable adoption of high-quality housing conditions (I.2.3): In the case of neighbourhood scale projects, the assessment of the indicator should focus on representative housing types within the project, e.g. based on type of tenure (homeownership or rental) and allocation criteria (market or affordable). In this example there is only one housing type (i.e. rentals and affordable). The social housing project increases living space, particularly for large families. Additionally, it enhances protection from both external and internal noise, along with energy efficiency through retrofitting. Rent cost for social housing is expected to increase by 7% after retrofitting. Since the provider received a public subsidy for the operation, at the indicator score is equal to I.2.3a = 30 (a-2 response in Table 160). I.2.3 is omitted from the assessment of the non-residential use.

Affordable access to services and amenities (I.2.4): The project is in a low-to-middle-income neighbourhood. On the ground floor of one building, it includes spaces dedicated to activities open to the neighbourhood: a youth space, a multipurpose hall, and some commercial spaces, which occupy one third of the ground floor. While no affordability criteria are established for the commercial spaces, the youth space and the multipurpose hall will offer all activities either free or at affordable prices. Since the youth space and multipurpose hall activities represent more than 50% of the provided services, a [c-5] response is considered in Table 161, I.2.4b = 100. I.2.4 is omitted from the assessment of the residential use.

I.2 score for the residential sub-project is calculated as:

$$I.2a = (0.35 \cdot 100 + 0.25 \cdot 100 + 0.2 \cdot 30)/(0.35 + 0.25 + 0.2) = 82.5 \tag{245}$$

I.2 score for the non-residential sub-project is calculated as:

$$I.2b = 100 \tag{246}$$

In both cases, the score corresponds to an Excellent performance class, and a performance class score of $PCS_{I.2}$ = 100.

5.6 Inclusive quality, equality and accessibility (I.3)

5.6.1 Description and assessment

To promote neighbourhood equality, it is crucial for projects providing housing and services to ensure that they contribute to improving residents' quality of life. This KPI assesses the extent to which the project ensures that the quality of created spaces and services is maintained over time, the distribution of services and their accessibility is equitable, and the production of spatial disparities is limited as much as possible through the choice of housing models that promote diversity and inclusion.

In the case of housing projects, the target of inclusive quality, quality and accessibility aims to enhance inclusiveness and meet the needs of the most disadvantaged families by promoting, on one hand, housing that adapts to the spatial needs of households based on their composition and, on the other hand, by encouraging renting as a preferred form of tenure. Both conditions, inadequate dwelling space for households and shortage of rental options, tend to affect low-income households more than others and produce socio-spatial inequalities.

Ensuring access to services and livelihood opportunities is crucial for inclusiveness (FMI, 2020b). Offering services and spaces that rapidly deteriorate in quality not only hinders but also undermines equality in the long term. For example, the lack of maintenance can be observed in the degradation of common or public spaces, more often in deprived neighbourhoods. This may lead to a reduction in the quality of life related to public health issues or an increase in conflicts among neighbours and must be avoided by NEB projects.

Finally, proximity of basic services and walkability at the neighbourhood scale have become a shared goal at the international level (UN-Habitat, 2023). Both services and walkability are regarded as essential for promoting equitable access to existing resources and opportunities, particularly for individuals living in deprived neighbourhoods who are most affected by the lack of access to basic services and amenities. In this context, a project should be assessed against whether it ensures an adequate walking distance from basic and fundamental services and amenities and from public transport. In addition, as a part of the NEB method the quality of services (such as transportation frequency or the presence of comfortable sidewalks) should be assessed. It is important for designers and project managers to be aware that these aspects must also be part of the design strategy.

While this approach adheres to the well-known principles of the 15-Minute City — which claims for a spatial distribution capable of making every resource within an easy reach (C40 Cities and ARUP, 2021) — it is also important to emphasise that, on its own, such an approach cannot be the solution to the fair redistribution issue. In fact, the 15-Minute City must be contextualised within the area of implementation, especially to avoid reinforcing segregation processes (Marchigiani and Bonfantini, 2022). This requires a deep understanding of the context rather than the application of predetermined models.

Under the KPI Inclusive quality, equality and accessibility (I.3), an assessment of the following indicators is performed:

- *Available dwelling space for households* (I.3.1).
- *Maintaining the quality of spaces and services* (I.3.2).
- *Rental scheme* (I.3.3).
- *Homeownership scheme* (I.3.4).
- *Pedestrian accessibility to essential services and amenities* (I.3.5).
- *Accessibility to services and amenities by public transport* (I.3.6).
- *Pedestrian accessibility to public transport* (I.3.7).

The total score of the KPI I.3 for Inclusive quality, equality and accessibility is calculated in the following way:

In the **general case**, when all indicators are considered, I.3 score is evaluated according to Equation (247).

$$I.3 = \sum_{j=1}^{7}(w_{I.3.j} \cdot I.3.j) \Big/ \sum_{j=1}^{7}(w_{I.3.j}) = \quad (247)$$

$$= 0.20 \cdot I.3.1 + 0.20 \cdot I.3.2 + 0.15 \cdot I.3.3 + 0.15 \cdot I.3.4 + 0.10 \cdot I.3.5 + 0.10 \cdot I.3.6 + 0.10 \cdot I.3.7 \leq 100$$

Five indicators (i.e. I.3.1, I.3.3, I.3.4, I.3.5, I.3.6) out of the seven that form the key performance indicator I.3 apply only to residential projects. These indicators will therefore be excluded from the calculation of the I.3 score for non-residential projects. Accordingly, in the case of **non-residential projects**, I.3 score is evaluated according to Equation (248).

$$I.3 = \sum_{j=1}^{7}(w_{I.3.j} \cdot I.3.j) \Big/ \sum_{j=1}^{7}(w_{I.3.j}) = \frac{0.20 \cdot I.3.2 + 0.10 \cdot I.3.7}{0.20 + 0.10} \leq 100 \quad (248)$$

Indicators I.3.3 and I.3.4 apply only to **residential projects** that involve **rental** and **homeownership** tenure, respectively. Projects that offer **both forms of tenure** must include both indicators in the evaluation of I.3, according to Equation (247). Projects that offer **either rental or homeownership** must include in the calculation only the indicator corresponding to the provided tenure and omit the other one, according to Equations (249) or (250), respectively

$$I.3 = \frac{0.2 \cdot I.3.1 + 0.2 \cdot I.3.2 + 0.15 \cdot I.3.3 + 0.1 \cdot I.3.5 + 0.1 \cdot I.3.6 + 0.1 \cdot I.3.7}{0.2 + 0.2 + 0.15 + 0.1 + 0.1 + 0.1} \leq 100 \tag{249}$$

$$I.3 = \frac{0.2 \cdot I.3.1 + 0.2 \cdot I.3.2 + 0.15 \cdot I.3.4 + 0.1 \cdot I.3.5 + 0.1 \cdot I.3.6 + 0.1 \cdot I.3.7}{0.2 + 0.2 + 0.15 + 0.1 + 0.1 + 0.1} \leq 100 \tag{250}$$

Each indicator is evaluated with a score between 0-100. The performance class of the I.3 key performance indicator is assessed according to the thresholds in Figure 112.

Figure 112. I.3 performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
I.3 thresholds ($t_{I.3}$):	$0 \leq$	$t_{I.3, Acceptable} \geq 40$	$t_{I.3, Good} \geq 60$	$t_{I.3, Excellent} \geq 80$	≤ 100

Source: JRC.

5.6.2 Available dwelling space for households (I.3.1)

Indicator I.3.1 applies only to **residential projects**.

The dwelling space available to a household, depending on the specific needs related to its composition, is crucial to ensure housing quality and health, wellbeing, and important outcomes such as children's and teenagers' education (OECD, 2021). Lack of intimacy, excess of stimulations and interactions is a source of stress and is found to have negative impacts on children's school performances and mental health (von Simson and Umblijs, 2021).

A household is considered overcrowded if it does not have at its disposal a minimum number of rooms equal to one room ([3]):

- for the household;
- for each couple in the household;
- for each single person aged 18 or more;
- for each pair of people of the same gender between 12 and 17;
- for each single person between 12 and 17 not included in the previous category;
- and for each pair of children under age 12.

Each room must provide the minimum size recommended by local standards with reference to its occupation.

Given this definition, the dwelling space of each housing unit must be assessed in relation to the household composition for which it was designed for. For example, if an apartment is designed and built for a household of four, according to the above-indicated criteria, it should be rent or sold to a relevant household composition.

If a building, neighbourhood or urban-scale project includes housing types with distinct attributes, e.g. housing units designed for different household compositions and/or different levels of space offered per household composition, the user may assess the most dominant housing type within the project. Alternatively, the user may perform multiple assessments corresponding to the distinct housing types. In the latter case, the indicator

[3] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Overcrowding_rate.

score is estimated as a weighted average, with the weights obtained from the relative occurrence of each housing type (in terms of number of housing units, area, or other features).

The assessment requires the following information to be identified and collected:

— Project design plans.

— Standards, guidelines and national standards relevant to minimum sizes per room.

— Number of housing units.

— Household composition for which each housing unit is designed.

A project is rewarded when the housing units satisfy minimum space requirements associated with the composition of the household that was adopted in their design.

The indicator is evaluated according to the question and the score provided in Table 162.

Table 162. I.3.1 score.

Metric: *Does the housing unit satisfy minimum space requirements associated with the composition of the household that was adopted in the design? (single selection allowed)*			
1. The housing unit does not provide the minimum necessary space. 2. The housing unit provides the minimum necessary space. 3. The housing unit provides space above[1] the recommended minimum.			
Indicator score	**[1]**	**[2]**	**[3]**
	0	70	100

[1] This refers either to the availability of at least one room more than the minimum, or to at least 15% more space than the minimum, as prescribed by local regulations.

Source: JRC.

Figure 113 shows the indicator thresholds used to link indicator scores with performance classes for I.3.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 113. I.3.1 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
I.3.1 thresholds ($t_{I.3.1}$):	0 ≤	$t_{I.3.1, Acceptable}$ ≥ 40	$t_{I.3.1, Good}$ ≥ 60	$t_{I.3.1, Excellent}$ ≥ 80 ≤ 100

Source: JRC.

5.6.3 Maintaining the quality of spaces and services (I.3.2)

Preventing the deterioration in the quality of project spaces and offered services is crucial for ensuring long-lasting impact, especially if these outcomes might affect vulnerable or marginalised people. Some phenomena at the neighbourhood level (e.g. lack of clear separation and use between public and private spaces; littering and environmental crime; inappropriate waste management; inadequate maintenance of streets/lighting/signage/buildings) may have a negative impact on the population's wellbeing and enjoyment of the place. While mechanisms of alarm and fixing are more appropriately set up at the neighbourhood level, similar monitoring of smaller places of inclusion can be implemented in a project to guarantee an adequate, fulfilling, and continually positive experience of place by its users. Monitoring further contributes to avoiding or mitigating disruptions, and timely intervening when they occur.

The goal of maintaining quality can be reached by defining a management strategy at the design phase of projects and allocating a budget for this purpose.

A strategy for the long-term maintenance of project outcomes and services must be designed through a partnership approach with all the relevant stakeholders, and it should include a monitoring plan, and an action plan.

At the **building** scale, plans should address the affordability of the offered services, energy savings, conflict resolution, the maintenance of common spaces where relevant, user satisfaction, safety issues, etc.

At the **neighbourhood** scale, plans should address the maintenance of common and public spaces, household solid waste management, safety issues, conflicts over uses in public spaces between different social groups, a monitoring system connected to higher decision-making levels, etc.

At the **urban** scale, plans must include at least a mapping of intervention areas organised by priority, a monitoring system aimed at identifying potential issues and organising quick responses, and coordination of the key stakeholders involved in maintenance and problem detection activities.

The indicator is evaluated according to the question and the score provided in Table 163.

Table 163. I.3.2 score.

Metric: *Is a strategy[1] in place for maintaining the quality of project spaces and services in the medium to long term? (single selection allowed)*				
1. A strategy is not included for the long-term maintenance of project spaces and services.				
2. A strategy for the long-term maintenance of project spaces and services exists but it is limited to some aspects only (e.g. management of common spaces), with or without a budget.				
3. A strategy for the long-term maintenance of project spaces and services is fully integrated into the project but no budget is allocated.				
4. An overall strategy that includes a plan and an appropriate budget is allocated for the long-term maintenance of project spaces and services.				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
	0	50	70	100

1 Strategy is affected by scale according to Section 5.6.3.

Source: JRC.

Figure 114 shows the indicator thresholds used to link indicator scores with performance classes for I.3.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 114. I.3.2 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
I.3.2 thresholds ($t_{I.3.2}$):	0 ≤	$t_{I.3.2,\ Acceptable}$ ≥ 40	$t_{I.3.2,\ Good}$ ≥ 60	$t_{I.3.2,\ Excellent}$ ≥ 80	≤ 100

Source: JRC.

5.6.4 Rental scheme (I.3.3)

Indicator I.3.3 applies only to **residential projects** that **adopt rental schemes**. The rental sector refers to the part of the housing market where residential properties are made available for rent to tenants. A rental scheme refers to the structured programs or plans through which tenants may have access to rental housing (e.g. subsidised, private, social housing).

Access to the rental market, whether free or subsidised, should be encouraged over homeownership within a regulated and controlled system (see Section 5.7.2).

Where a project chooses, either wholly or partially, rental as form of tenure, it is important that the adopted scheme promotes an equitable distribution of rental options in the area, both free and subsidised, considering that affordable solutions are preferable to the free market as they promote access to housing for households in more disadvantaged conditions.

Projects need to be compared against the rental sector existing in context, to assess whether the choice of the rental scheme promotes equality. For example, in contexts where the share of private rental is dominant over other schemes, projects that promote forms of subsidised or social rental are rewarded with higher scores.

The assessment of the indicator should consider the different types of rental schemes within a building, neighbourhood or urban scale project. The user may assess the most dominant rental scheme. Alternatively, the user may perform multiple assessments corresponding to the distinct rental schemes. In the latter case, the indicator score is estimated as a weighted average, with the weights obtained from the relative occurrence of each scheme.

The assessment requires the following information to be identified and collected:

— Information about the local rental system (at the urban level).

— The adopted rental scheme for the project.

The indicator is evaluated according to the question and the score provided in Table 164.

Table 164. I.3.3 score.

Contextual variance: *How is the rental sector characterised at the urban level? (single selection allowed)*				
a. Dominant private market. b. Moderate share of subsidised and social rental (>15% and < 25%). c. Large share of subsidised and social rental (≥25%).				
Metric: *What is the rental scheme that is adopted by the project? (single selection allowed)*				
1. Private rental at market price. 2. Private rental at an affordable price (agreed rents). 3. Private rental with rent allowances. 4. Social rental.				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
[a]	0	55	75	100
[b]	0	45	65	95
[c]	0	35	55	90

Source: JRC.

Figure 115 shows the indicator thresholds used to link indicator scores with performance classes for I.3.3. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 115. I.3.3 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
I.3.3 thresholds ($t_{I.3.3}$):	$0 \leq$	$t_{I.3.3,\ Acceptable} \geq 40$	$t_{I.3.3,\ Good} \geq 60$	$t_{I.3.3,\ Excellent} \geq 80$	≤ 100

Source: JRC.

5.6.5 Homeownership scheme (I.3.4)

Indicator I.3.4 applies to **residential projects** that **adopt homeownership schemes**. Homeownership schemes are initiatives designed to assist households in purchasing and owning homes. These schemes can include a range of financial assistance and policy measures and can be individual or collective.

As widely demonstrated in the literature (e.g. Aalbers, 2019), the financialisation of the housing market and commodification of housing make private homeownership a form of tenure that tends to exacerbate the production of social and spatial inequality.

While de-commodification is a phenomenon that must be addressed at a policy level, at the project scale tenancy should be favoured over homeownership, which has traditionally been the reference tenure in housing policies (Schmid, 2018).

If a project includes, either wholly or partially, private ownership as a form of tenure, the most inclusive form is collective ownership (e.g. cooperatives, community land trusts, co-housing) rather than individual ownership, as the former ensures greater stability and promotes forms of collaboration and mutual support.

The assessment of the indicator should consider the different types of homeownership schemes within a building, neighbourhood or urban scale project. The user may assess the most dominant homeownership scheme. Alternatively, the user may perform multiple assessments corresponding to the distinct homeownership schemes. In the latter case, the indicator score is estimated as a weighted average, with the weights obtained from the relative occurrence of each scheme.

The assessment requires the following information to be identified and collected:

— Information about the local housing sector in relation to homeownership (at the urban level).

— The project homeownership scheme.

The indicator is evaluated according to the questions and the score matrix provided in Table 165.

Table 165. I.3.4 score.

Contextual variance: *How is the housing sector characterised at the urban level in relation to homeownership? (single selection allowed)*			
a. Dominant private market homeownership (> 60%). b. Mix of private market and subsidised homeownership (both < 60%). c. Dominant subsidised homeownership (> 60%).			
Metric: *What is the homeownership scheme adopted by the project? (single selection allowed)*			
1. Individual market homeownership. 2. Collective homeownership. 3. Individual subsidised homeownership.			
Indicator score	**[1]**	**[2]**	**[3]**
[a]	0	35	70
[b]	0	30	60
[c]	0	25	50

Source: JRC.

Figure 116 shows the indicator thresholds used to link indicator scores with performance classes for I.3.4. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 116. I.3.4 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
I.3.4 thresholds ($t_{I.3.4}$):	$0 \leq$	$t_{I.3.4,\ Acceptable} \geq 40$	$t_{I.3.4,\ Good} \geq 60$	$t_{I.3.4,\ Excellent} \geq 80$ ≤ 100

Source: JRC.

5.6.6 Pedestrian accessibility to essential services and amenities (I.3.5)

Indicator I.3.5 applies only to **residential projects**.

Pedestrian accessibility is understood as the residents' ability to reach essential services and amenities in their neighbourhood. Proximity to basic services is acknowledged as central to promoting health and reducing inequalities. To basic services, which include healthcare (pharmacies) and education (primary school), essential amenities are added, meaning those facilities that enhance the quality of life and the liveability of a neighbourhood, such as food shopping (groceries and supermarkets) and open public spaces (playgrounds, parks, green areas).

Considering only these essential services, 5 minutes are adopted as the optimal walking access time for pedestrian accessibility.

To assess the project accessibility to essential services and amenities, the following steps can be followed. The steps are based on the Sustainable Development Goals (SDG) Transformation Centre (2023). However, the adopted steps here are simplified and exclude calculations related to population:

— Localise essential services and amenities on a georeferenced spatial database (e.g. OpenStreetMap) within an area including the project. The area is practically limited by the identification of the closest services and amenities as explained below.

— Identify the departure points within the project scale and destination points. Departure points are defined either as the building coordinates for building scale projects, or as the coordinates of all street intersection within the project scale for neighbourhood and urban scale projects. Destinations refer to the coordinates of services and amenities. For each type of service or amenity (Table 166), only the closest one is used in evaluating the average distance in the next step. At least four destinations per departure point should be considered, corresponding to at least one service/amenity type of healthcare, education, food shopping and open public space.

Table 166. Services and amenities considered in assessing pedestrian accessibility.

Essential services	**Types**		
Healthcare	Pharmacy		
Education	Primary school		
Essential amenities	**Types**		
Food shopping	Grocery	Supermarket	
Open public space	Playground	Park	Green area

Source: JRC.

— Measure the distance from each departure point to the closest essential amenities and services (i.e. the considered destinations per departure point). Calculate the average walking distance per departure point. This is defined as the arithmetic mean of distances from a departure point to the corresponding destinations. For neighbourhood and urban scale projects, calculate the average distance as the arithmetic mean of the mean distances calculated for all departure points.

— Transform the average distance into walking time assuming an average pedestrian walking speed of 4.8 km/h.

If the project is at the **urban** scale, it is suggested to divide the project area into sub-areas. For example, by overlaying a 1000-metre grid onto the project area, it is possible to calculate first the average distance within each grid, and then compute an average distance at the urban scale. This allows identifying potential gaps and intervening in the project design to enhance accessibility.

The assessment requires the following information to be identified and collected:

— Project design plans.

— Identification and localisation of essential services and amenities within an area including the project (e.g. 1000 metres from the perimeter of the project), with the possibility to expand it if an essential service or amenity cannot be found within this range.

Using the estimated walking time, the indicator is evaluated according to the question and the score provided in Table 167.

Table 167. I.3.5 score.

Metric: *What is the level of pedestrian accessibility[1] to essential services and amenities? (single selection allowed)*				
1. Pedestrian accessibility to essential services and amenities is more than 15 minutes.				
2. Pedestrian accessibility to essential services and amenities is between 11 and 15 minutes.				
3. Pedestrian accessibility to essential services and amenities is between 6 and 10 minutes.				
4. Pedestrian accessibility to essential services and amenities is less than 5 minutes.				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
	0	50	70	100

[1] Pedestrian accessibility evaluated according to Section 5.6.6.

Source: JRC.

Figure 117 shows the indicator thresholds used to link indicator scores with performance classes for I.3.5. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 117. I.3.5 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.3.5 thresholds ($t_{I.3.5}$):	0 ≤		$t_{I.3.5,\ Acceptable}$ ≥ 40		$t_{I.3.5,\ Good}$ ≥ 60		$t_{I.3.5,\ Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.6.7 Accessibility to services and amenities by public transport (I.3.6)

Indicator I.3.6 applies only to **residential projects**.

The essential services and amenities identified for indicator I.3.5 must be reachable on foot to ensure optimal accessibility and that basic needs are satisfied. Ensuring fair access through public transportation to services and amenities is equally important from a spatial justice perspective (Tahmasbi and Haghshenas, 2019). Indicator I.3.6 measures the travel time from the project to destinations that offer such opportunities according to Table 168.

Table 168. Services and amenities considered in assessing accessibility by public transport.

Services	**Types**	
Healthcare	Hospital	Health facility
Education	Secondary school	
Amenities	**Types**	
Shopping	Retail area	Central district
Leisure	Park	Sport hall

Source: JRC.

To assess the accessibility of projects to services and amenities by public transport, the NEB method adopts the following steps:

— Localise services and amenities on a georeferenced spatial database (e.g. OpenStreetMap) within an area including the project. The area is practically limited by the identification of the closest services and amenities as explained below.

— Identify the departure points within the project scale and destination points. Departure points are defined either as the building coordinates for building scale projects, or as the coordinates of all street intersection within the project scale for neighbourhood and urban scale projects. Destinations refer to the coordinates of services and amenities. For each type of service or amenity (Table 168), only the closest one is used in evaluating the average travel time by public transport in the next step. At least four destinations per departure point should be considered, corresponding to at least one service/amenity type of healthcare, education, shopping and leisure.

— By using local public transit applications (or similar software), calculate the travel time from each departure point to the closest services and amenities (i.e. the considered destinations per departure point). Calculate the average travel time per departure point. This is defined as the arithmetic mean of travel times from a departure point to the corresponding destinations. For neighbourhood and urban scale projects, calculate the average travel time as the arithmetic mean of the mean travel times calculated for all departure points.

If the project is at the **urban** scale, it is suggested to divide the project area into sub-areas. For example, by overlaying a 1000-metre grid onto the project area, it is possible to calculate the travel time first within each grid, and then compute an average travel time at the urban scale. This allows identifying potential gaps and intervening in the project design to enhance accessibility to services and amenities by public transport.

The assessment requires the following information to be identified and collected:

— Project design plans.

— Identification and localisation of public transport stops on a georeferenced spatial database.

— Identification and localisation of the closest services and amenities from Table 168 on a georeferenced spatial database, within an area including the project.

Using the estimated average travel time, the indicator is evaluated according to the question and the score provided in Table 169.

Table 169. I.3.6 score.

Metric: *What is the level of accessibility by public transport[1] to services and amenities? (single selection allowed)*				
1. The average travel time by public transport is ≥ 30 minutes. 2. The average travel time by public transport is ≥ 22.5 and < 30 minutes. 3. The average travel time by public transport is ≥ 15 and < 22.5 minutes. 4. The average travel time by public transport is < 15 minutes.				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
	0	50	70	100

1 Accessibility by public transport evaluated according to Section 5.6.7.

Source: JRC.

Figure 118 shows the indicator thresholds used to link indicator scores with performance classes for I.3.6. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 118. I.3.6 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.3.6 thresholds ($t_{I.3.6}$):	0 ≤		$t_{I.3.6, Acceptable}$ ≥ 40		$t_{I.3.6, Good}$ ≥ 60		$t_{I.3.6, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.6.8 Pedestrian accessibility to public transport (I.3.7)

This indicator evaluates the level of pedestrian accessibility provided by the project to public transport stops, regardless of the transport mode (bus, metro, tram, train). It is measured as the average distance to the nearest public transport stops, assuming that people are willing to walk 500 metres to reach a transport stop (Poelman et al., 2020).

The proximity to public transport not only encourages the use of greener modes of transport, but also promotes social inclusion through better accessibility to job opportunities, education, and healthcare.

To assess the accessibility of projects to public transport, the following steps can be followed. The steps are based on the SDG Transformation Centre (2023). However, the adopted steps here are simplified and exclude calculations related to population:

— Localise public transport stops on a georeferenced spatial database (e.g. OpenStreetMap) within an area including the project. The area is practically limited by the identification of the closest public transport stops.

— Identify the departure points within the project scale and destination points. Departure points are defined either as the building coordinates for building scale projects, or as the coordinates of all street intersection within the project scale for neighbourhood and urban scale projects. Destinations refer to the coordinates of the closest public transport stops to the departure points (i.e. one stop per departure point).

— Measure the distance from each departure point to the closest public transport stop (i.e. the considered destination per departure point). For neighbourhood and urban scale projects, calculate the average distance as the arithmetic mean of distances calculated for all departure points.

If the project is at the **urban** scale, it is suggested to divide the project area into sub-areas. For example, by overlaying a 1000-metre grid onto the project area, it is possible to first calculate the average distance within each grid, and then compute an average distance at the urban scale. This allows identifying potential gaps and intervening in the project design to enhance accessibility to public transport.

The assessment requires the following information to be identified and collected:

- Project design plans.
- Identification and localisation of public transport stops on a georeferenced spatial database, within an area including the project (e.g. 1000 metres from the perimeter of the project).

Using the average distance to public transportation stops, the indicator is evaluated according to the question and the score provided in Table 170.

Table 170. I.3.7 score.

Metric: *What is the level of pedestrian accessibility[1] to public transport? (single selection allowed)*				
1. The average distance to public transport stops is more than 800 m. 2. The average distance to public transport stops is between 500 and 800 m. 3. The average distance to transport stops is between 300 and 500 m. 4. The average distance to transport stops is less than 300 m.				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
	0	50	70	100

[1] Pedestrian accessibility to public transport evaluated according to Section 5.6.8.

Source: JRC.

Figure 119 shows the indicator thresholds used to link indicator scores with performance classes for I.3.7. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 119. I.3.7 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.3.7 thresholds ($t_{I.3.7}$):	0 ≤		$t_{I.3.7, Acceptable}$ ≥ 40		$t_{I.3.7, Good}$ ≥ 60		$t_{I.3.7, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.6.9 Example (I.3)

In a context with a large share of subsidised and social rental (i.e. 25%), and a housing sector with dominant private market homeownership (compared to the subsidised one), a project involves the construction of a new neighbourhood comprising five buildings, of which four are residential buildings and one is for office use. On the ground floor of two buildings, there will be local commercial spaces (including a grocery store and a pharmacy). Out of the four residential buildings, one is designated for sale on the market for homeownership, while three are intended for rental. Since the neighbourhood scale project includes mixed use, the user will need to classify the project based on the most dominant aspect and assess only this one at the scale of the complete project. Alternatively, the user may opt to assess the project as two individual projects, one addressing residential use, and one addressing non-residential use, both assessed at the scale of the complete project as follows:

Project classification – a: Neighbourhood – Newbuild – Residential

Project classification – b: Neighbourhood – Newbuild – Non-residential

The second approach is followed in the following.

Available dwelling space for households (I.3.1): For the residential use, the project respects the minimum standards for the required space and associates the incoming residents to the apartment typology based on the household composition. Considering a [2] response in Table 162, the indicator achieves a score of I.3.1a = 70. This indicator does not apply to the non-residential use.

Maintaining the quality of spaces and services (I.3.2): For the residential use, there is a management plan developed by the housing provider with budget allocation, but it is partial and only includes cleaning and maintenance of common areas. Considering a [2] response in Table 163, the indicator achieves for the residential component a score of I.3.2a = 50. To improve this score, the provider should collaborate with future residents to design a collective management plan that includes all aspects considered important for the quality of life at the building and neighbourhood level. This plan should also allocate the corresponding budget. For the non-residential use (office building and commercial spaces), there is an overall strategy for maintenance, which includes a budget. Considering a [4] response in Table 163, the indicator achieves a score of I.3.2b = 100.

Rental scheme (I.3.3): Three residential buildings out of the four are intended for rent and one for homeownership. Two thirds of the housing units in the three rental buildings are intended for social rent and one third for rent at market price. Considering [c-1 and c-4] responses in Table 164, the indicator achieves a score of I.3.3a = (1/3) · 0 + (2/3) · 90 = 60. The indicator does not apply to the office building and the residential building that is intended for homeownership.

Homeownership scheme (I.3.4): The residential building intended for homeownership will provide individual ownership. Considering an [a-1] response in Table 165, the indicator achieves a score of I.3.4a = 0. The indicator does not apply to the office building and the three residential buildings that are intended for rental (assessed by I.3.3).

Pedestrian accessibility to essential services and amenities (I.3.5): The new neighbourhood is close to essential services and amenities, and it includes three street intersections which define the departure points. For each departure point the average distance is first calculated from four types of services and amenities at the closest distance according to Table 171. Subsequently, the average distance of the neighbourhood to services and amenities is calculated as the average of the departure point distances. The average distance is transformed to walking time according to Equation (251). Considering a [4] response in Table 167, the indicator achieves a score of I.3.5a = 100. The indicator does not apply to non-residential use.

Table 171. Assessment of pedestrian accessibility to essential services and amenities.

Departure points	**Closest distance from following destinations (m):**				
	Pharmacy	**Primary school**	**Grocery**	**Green area**	**Average**
Street intersection 1	80	450	80	450	265
Street intersection 2	200	300	200	300	250
Street intersection 3	180	400	180	400	290
Average distance from all intersections (m)					**268.3**

Source: JRC.

$$t = \frac{0.268\ km}{4.83\ km/h} \cdot 60 = 3.33\ minutes \tag{251}$$

Accessibility to services and amenities by public transport (I.3.6): At least one type per service and amenity must be considered from Table 168. In this example the services and amenities of Table 172 are considered. The average travel time for street intersections 1 and 2 is the same, since the same bus and tram stops service them to the same hospital, primary school, retail area and sport hall. Considering a [3] response in Table 169, the indicator achieves a score of I.3.6a = 70. The indicator does not apply to non-residential use.

Table 172. Assessment of accessibility to services and amenities by public transport.

Departure points	**Closest travel time from following destinations (minutes):**				
	Hospital (by bus)	**Secondary school (by bus)**	**Retail area (by tram)**	**Sport hall (by bus)**	**Average**
Street intersection 1	25	16	22	10	18.25
Street intersection 2	25	16	22	10	18.25
Street intersection 3	29	20	26	14	22.25
Average travel time from all intersections (minutes)					**19.58**

Source: JRC.

Pedestrian accessibility to public transport (I.3.7): There are two public transport stops (A, B) close to the neighbourhood. Each stop serves both bus and tram lines. Stop A is closer to street intersections 1 and 2, whereas stop B is closer to street intersection 3, according to Table 173. Considering a [4] response in Table 170 based on the average distance among the three intersections, the indicator achieves a score of I.3.7a, b = 100.

Table 173. Assessment of pedestrian accessibility to public transport.

Departure points	**Closest distance from following destinations (m):**	
	Bus and tram stop A	**Bus and tram stop B**
Street intersection 1	150	—
Street intersection 2	175	—
Street intersection 3	—	450
Average distance from all intersections (m)		**258**

Source: JRC.

The key performance indicator I.3 is calculated as follows for the residential and non-residential aspects of the project:

$$I.3a = 0.2 \cdot 70 + 0.2 \cdot 50 + 0.15 \cdot 60 + 0.15 \cdot 0 + 0.1 \cdot 100 + 0.1 \cdot 70 + 0.1 \cdot 100 = 60 \qquad (252)$$

$$I.3b = (0.2 \cdot 100 + 0.1 \cdot 100)/0.3 = 100 \qquad (253)$$

The scores correspond to Good and Excellent performance classes for residential and non-residential use, respectively, with performance class scores of $PCS_{I.3a}$ = 75 and $PCS_{I.3b}$ = 100.

5.7 Rent regulation (I.4)

5.7.1 Description and assessment

Measures on financial instruments (Section 5.4) affect housing affordability indirectly – taming financialisation and promoting a financial environment that is favourable to affordability. These measures should be complemented by direct ones regulating access of households to rental options, when available, for example by regulating rent prices. Such regulation is particularly necessary to maintain affordable rental markets, which are especially volatile and have historically impacted housing regimes across various tenures. Rent regulation involves imposing certain limitations on the rents of rental dwellings. Rent control has been, historically, one of the most effective instruments for maintaining housing affordability and preventing eviction, displacement, and homelessness (Slater, 2021). Rent regulation in the free market varies greatly among European countries. According to recent comparative research (Kettunen and Ruonavaara, 2021), most European countries have rental sectors dominated by the free market. Despite the progressive deregulation of housing and particularly rental markets, various systems of rent control are still present across Europe. For the self-assessment method, the scheme proposed by Kettunen and Ruonavaara (2021, p. 1452) is adopted. According to the scheme, the types of tenancy legislation in different countries are mapped across Europe. Three types are identified, based on the restrictiveness of current legislation: from the least restrictive and most liberalised (free markets), to those that have some rules, such as rent increase control (third generation), and the most restrictive and regulated (second generation). Although, like all classifications, this one also has its limitations, for the purpose of self-assessment it is a good guide to properly identify the context of the project. Free markets, second generation and third generation on the map correspond to “liberalised rental market”, “fairly regulated” and “strongly regulated” in Table 174 and Table 175 below.

Rental regulations can be broken down into two fundamental categories:

- Security of tenure: establishing an indefinite duration of occupancy as well as limitations on justifications for eviction of tenants.

— Rent stabilisation: controlling level and frequency of rent increases and setting caps on rents for new contracts, both with the aim to preserve affordability, preclude de facto economic eviction, and safeguard the accessibility to affordable housing as well as mobility in changing labour markets (IUT, 2018).

Projects adopting rental schemes should guarantee tenure stability and improve affordability compared to existing rent regulation, or adopt ad hoc rent control mechanisms where regulations are absent or limited.

Under the KPI Rent regulation (I.4), an assessment of the following indicators is performed:

— *Rental contracts* (I.4.1)

— *Rents setting* (I.4.2)

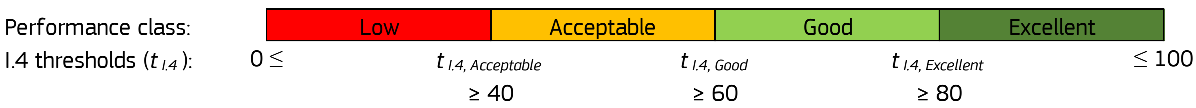
I.4 score is evaluated according to Equation (254) for **residential projects** that provide **rental** options.

$$I.4 = \sum_{j=1}^{2}\left(w_{I.4.j} \cdot I.4.j\right) \Big/ \sum_{j=1}^{2}\left(w_{I.4.j}\right) = 0.35 \cdot I.4.1 + 0.65 \cdot I.4.2 \leq 100 \qquad (254)$$

I.4 does not apply to residential projects with no rental options and to non-residential projects, and is therefore omitted from the calculation of the dimension score (Equation (240)) in such cases.

Each indicator is evaluated with a score between 0-100. The performance class of the I.4 key performance indicator is assessed according to the thresholds in Figure 120.

Figure 120. I.4 performance classes and thresholds.



Source: JRC.

5.7.2 Rental contracts (I.4.1)

I.4.1 applies only to **residential projects** that **adopt rental schemes**.

Projects adopting rental as tenure type should guarantee tenure stability as much as possible. Projects that propose rental contracts with indeterminate duration are particularly encouraged because they offer tenants security against eviction and displacement. This entails establishing an indefinite duration of occupancy as well as setting limitations on the eviction of tenants. On the contrary, where short-term rentals are abundant, the risk of unaffordability and displacement is higher, therefore such rentals should be avoided or limited.

The capacity of projects to ensure stability of tenure must be measured in relation to the existing regulatory framework protecting tenants from eviction and displacement.

The assessment requires the following information to be identified and collected:

— Information about the local rental sector regulatory framework.

— Types of rental contracts planned by the project.

Accordingly, in the evaluation of I.4.1 (Table 174), projects are discouraged from including short-term contracts and rewarded when promoting indeterminate duration of contracts.

Table 174. I.4.1 score.

Contextual variance: *How would you describe the local rental market in terms of regulatory capacity?* [1] *(single selection allowed)*					
a. Strongly regulated (the rental sector controls the market through rent caps and rent stabilisation measures).					
b. Fairly regulated (the rental sector includes some regulations to control rent prices with limited scope).					
c. Liberalised (the rental sector is entirely controlled by the market).					
Metric: *What types of rental contracts are available by the project? (single selection allowed)*					
1. Only fixed term and short-term rental contracts are offered.					
2. Only fixed-term rental contracts are offered.					
3. A mix of fixed-term and unlimited duration contracts are offered. Fixed-term rental contracts are the majority.					
4. A mix of fixed-term and unlimited duration contracts are offered. Unlimited duration rental contracts are the majority.					
5. Only unlimited duration rental contracts are offered.					
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
[a]	0	20	45	65	100
[b]	0	25	50	70	100
[c]	10	30	70	90	100

[1] The extent to which a project can promote affordability through rental regulation depends on the existing rental market (including social rental).

Source: JRC.

Figure 121 shows the indicator thresholds used to link indicator scores with performance classes for I.4.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 121. I.4.1 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
I.4.1 thresholds ($t_{I.4.1}$):	$0 \leq$	$t_{I.4.1, Acceptable} \geq 40$	$t_{I.4.1, Good} \geq 60$	$t_{I.4.1, Excellent} \geq 80$	≤ 100

Source: JRC.

5.7.3 Rents setting (I.4.2)

Indicator I.4.2 applies only to **residential projects** that **adopt rental schemes**.

Residential projects adopting rental as tenure type should promote affordability according to existing rent regulation policies or adopt ad hoc rent control mechanisms that include rent caps and rent stabilisation. These mechanisms are essential for ensuring affordability in the medium to long term because they control and limit rent increases over time or impose rent caps for new contracts. Moreover, such instruments make tenants displacement less likely in urban transformation processes. In particular, ad hoc mechanisms are key in contexts with no rental regulatory framework or where the regulatory framework is too weak to ensure affordability. Even though rent regulation in the private market does not only involve rent control, but also includes the regulation of relationships between tenants and landlords and other aspects (Kettunen and Ruonavaara, 2021), the self-assessment method for the sake of simplicity focuses only on the rent control aspect.

To assess how the project sets the rent and whether it promotes affordability, the housing sector shall be considered either as:

— Market rental-based sector: access to housing is based on tenants and landlords meeting in the market, where housing is allocated based on demand and supply. Rent regulation may be regulated and enforced by the government but it can have different level of strictness across countries (Haffner et al., 2009). Projects that set rents in a liberalised market sector can choose to establish ad hoc rent control mechanisms that are stricter than existing regulation, to support affordability.

or

— Social rental-based sector: access to housing is politically defined, regulated by the government and based on needs. Rents are always below market price and are subsidised.

Indicator I.4.2 rewards projects that, despite operating in a liberalised context, introduce a system of targeted rules to ensure affordability over time. At the same time, projects that allocate all units (i.e. dwellings) at market prices receive lower score.

The assessment requires the following information to be identified and collected:

— Information about the local rental sector regulatory framework.

— Rent setting at the project level.

The indicator is evaluated according to the questions and the score matrix provided in Table 175.

Table 175. I.4.2 score.

Contextual variance: *How would you describe the local rental market in terms of regulatory capacity?*[1] *(single selection allowed)*					
a. Strongly regulated (the rental sector controls the market through rent caps and rent stabilisation measures).					
b. Fairly regulated (the rental sector includes some regulations to control rent prices with limited scope).					
c. Liberalised (the rental sector is entirely controlled by the market).					
Metric: *How are rents set by the project? (single selection allowed)*					
1. Rents are set above the market price in the neighbourhood.					
2. Rents are set according to market price in the neighbourhood.					
3. Rents are set partly at market price and partly according to local rent or ad hoc control regulations that compensate for limited/non-existing regulations.					
4. Rents are set according to local rent control regulations.					
5. Rents are set according to ad hoc rent control mechanisms.					
Indicator score[2]	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
[a]	0	10	45	70	85
[b]	0	20	50	85	90
[c]	0	30	65	—	100

1 The extent to which a project can promote affordability through rental regulation depends on the existing rental market (including social rental).

2 Dashes correspond to options that cannot be selected by the user, given the contextual variance.

Source: JRC.

Figure 122 shows the indicator thresholds used to link indicator scores with performance classes for I.4.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 122. I.4.2 indicative performance classes and thresholds.

Performance class:	Low		Acceptable		Good		Excellent	
I.4.2 thresholds ($t_{I.4.2}$):	0 ≤	$t_{I.4.2,\ Acceptable}$ ≥ 40		$t_{I.4.2,\ Good}$ ≥ 60		$t_{I.4.2,\ Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.7.4 Example (I.4)

The project that was used as an example in Section 5.6.9, is employed also here for the evaluation of I.4. Since the neighbourhood scale project includes mixed use, the user will need to classify the project based on the most dominant aspect and assess only this one at the scale of the complete project. Alternatively, the user may opt to assess the project as two individual projects, one addressing residential use, and one addressing non-residential use, both assessed at the scale of the complete project as follows:

Project classification – a: Neighbourhood – Newbuild – Residential

Project classification – b: Neighbourhood – Newbuild – Non-residential

The second approach is followed in the following.

For non-residential use, I.4b is omitted from the calculation of the dimension score, and below only the residential use is evaluated.

Rental contracts (I.4.1): The project is in a region where rental market is fairly regulated. The rental contracts for the housing units in this project are all fixed-term, and conditions are reviewed every three years. This limited duration does not guarantee security of tenure. Considering a [b-2] response in Table 174, the indicator achieves a score of I.4.1a = 25. To improve performance, the project needs to transition from fixed-term contracts to indefinite-duration contracts.

Rents setting (I.4.2): In the context of the project some regulations exist, such as rent caps with limitations. The housing units assigned for rent by the project have contracts set according to those existing regulations. Considering a [b-4] response in Table 175, the indicator achieves a score of I.4.2a = 85. To improve this, rents should be set according to ad hoc regulations that are stricter and more favourable to tenants than existing ones.

The key performance indicator I.4 for residential use is calculated as:

$$I.4a = 0.35 \cdot 25 + 0.65 \cdot 85 = 64 \quad (255)$$

The score corresponds to a Good performance class, and a performance class score of $PCS_{I.4a}$ = 75.

5.8 Impact on neighbourhood social cohesion (I.5)

5.8.1 Description and assessment

The key performance indicator aims to evaluate how designers address the potential impacts of projects on the social cohesion within buildings and neighbourhoods. Specifically, I.5 evaluates whether the project minimises the effects of social segregation and exclusion that may result from the concentration of homogeneous social groups in an area or from discriminatory and unfair design practices.

Segregation can take various forms: the creation of homogeneous areas of poverty or wealth, both equally problematic; segregation at the micro-scale, which can take place within neighbourhoods, dividing residents by socioeconomic status and ethnicity, and even within residential buildings between floors or between the front and back of a building (Maloutas and Karadimitriou, 2022).

Gentrification is the process that happens when less affluent residents are replaced over time with more affluent residents, involving a reinvestment of capital in the built environment (Davidson and Lees, 2005), the increase of housing prices and a comprehensive change in the neighbourhood that becomes more attractive to wealthier segments of the population (sometimes also for tourists) and less accessible to lower-income groups. This process often entails direct or indirect displacement of the existing residents who are pushed out of the area where they live to more affordable neighbourhoods. Along this process, which can bring eventually segregation effects, the rights and agency of the original residents are overlooked, along with the value of their social networks, their feeling of belonging and attachment to their home and neighbourhood.

Projects are not assessed in terms of their possible impact on segregation at the urban scale. The urban impact is a matter of urban public policies beyond the planning potential of projects. The segregation impact for the whole urban area is complex and the assessment is limited to the neighbourhood level: some negative developments (e.g. a gentrification process in its early stages within a working-class neighbourhood) can appear positive for segregation since they increase social mix at the neighbourhood level, at least for some time. Moreover, the measurement of residential segregation using the index of dissimilarity and many other segregation indices (Coulter, 1989) is very difficult to harmonise across Europe, since data on social categories vary across national contexts and not always accessible at a spatial level below the neighbourhood (e.g. census tract). Therefore, the impact of projects using KPI 5.8 is assessed only at the neighbourhood level, even in the case of building and urban scale projects.

To curb processes of segregation and gentrification, as well as their negative impact, the project, at the very least, must take some countermeasures such as the following:

— When providing housing, ensure that the typology mix at the neighbourhood level is not reduced. Typology mix is essential in securing equal access to housing across neighbourhoods. However, it is also essential as the means to provide opportunities for staying in gentrifying neighbourhoods to those of more limited resources.

— To support inclusion at neighbourhood level, it is also essential to promote equality within and across neighbourhoods, through a fair distribution of services and spaces of quality. According to the EU Pillar of Social Rights (European Commission, 2017), necessary to address the challenge posed by the need for ensuring the availability, quality, and access to a wide variety of services across cities and regions.

— Take action to prevent segregation or gentrification, depending on the economic status (or trend) of the project area

— Fostering a sense of belonging and comfort within a neighbourhood, involves providing all residents with opportunities for involvement and encouraging cohesion within and among resident groups. This requires offering a variety of services, activities, and organisational structures capable of raising awareness and actively engaging residents, to enable existing communities to thrive and new relationships to form. It is particularly important in areas experiencing demographic shifts, to prevent the emergence of divisions between established and incoming residents.

Under the KPI Impact on social cohesion of neighbourhoods (I.5), an assessment of the following indicators is performed:

— *Housing typology mix* (I.5.1)

— *Prevention of segregation at the micro scale* (I.5.2)

— *Prevention of gentrification and displacement* (I.5.3)

— *Outreach activities for project-related social and cultural services* (I.5.4)

The evaluation of the key performance indicator depends on the classification of the project regarding the scale and main use (residential or non-residential) according to Table 155, and in addition on the economic status in the project area. Some non-exhaustive examples are considered below.

In the case of **building** and **neighbourhood-scale residential projects** within a **wealthy** or **gentrified area**, the evaluation of I.5 excludes indicator I.5.3, according to Equation (256).

$$I.5 = \sum_{j=1}^{4} (w_{I.5.j} \cdot I.5.j) \Big/ \sum_{j=1}^{4} (w_{I.5.j}) = \frac{0.3 \cdot I.5.1 + 0.2 \cdot I.5.2 + 0.2 \cdot I.5.4}{0.3 + 0.2 + 0.2} \leq 100 \quad (256)$$

In the case of **neighbourhood projects** within a **low to middle-income** or **gentrifying area**, the evaluation of I.5 excludes indicator I.5.2, according to Equation (257).

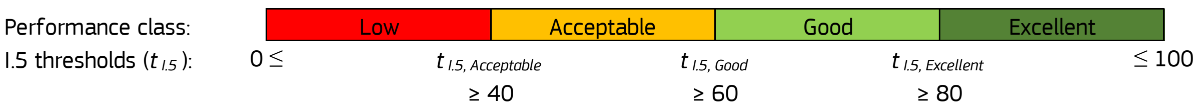
$$I.5 = \sum_{j=1}^{4} (w_{I.5.j} \cdot I.5.j) \Big/ \sum_{j=1}^{4} (w_{I.5.j}) = \frac{0.3 \cdot I.5.1 + 0.3 \cdot I.5.3 + 0.2 \cdot I.5.4}{0.3 + 0.3 + 0.2} \leq 100 \quad (257)$$

Non-residential projects, exclude both I5.1 and I5.2 indicators, according to Equation (258). The presence of I.5.3 further indicates that Equation (258) refers to a **neighbourhood project** within a **low to middle-income** or **gentrifying area**.

$$I.5 = \sum_{j=1}^{4} (w_{I.5.j} \cdot I.5.j) \Big/ \sum_{j=1}^{4} (w_{I.5.j}) = \frac{0.3 \cdot I.5.3 + 0.2 \cdot I.5.4}{0.3 + 0.2} \leq 100 \quad (258)$$

Each indicator is evaluated with a score between 0-100. The performance class of the I.5 key performance indicator is assessed according to the thresholds in Figure 123.

Figure 123. I.5 performance classes and thresholds.



Source: JRC.

5.8.2 Housing typology mix (I.5.1)

Indicator I.5.1 applies only to **neighbourhood** and **urban**-scale projects of **residential** use.

The variety of housing types that a project provides should respond to different local needs that may change over the years, based on the number of family members, cultural requirements, and economic conditions. This diversity also aligns with objectives aimed to prevent segregation.

Typology mix can be expressed by the following elements.

Typology mix can be expressed primarily in terms of house typology (detached, semi-detached, row housing, multi-family housing). Within each typology, some variation may concern also size (e.g. area in square metres and number of rooms per housing unit) and size of outdoor space per housing unit (including backyards and balconies). For the self-assessment method, the housing typology is considered (disregarding size) for simplification reasons.

In all contexts, a limited mix in the typology of housing units (e.g. providing only one housing typology) is considered negative because it decreases the opportunities for a socioeconomic mix. In the case of urban scale projects, the assessment of the indicator should be performed separately for each neighbourhood. The indicator score is finally estimated as a weighted average, with weights based on neighbourhood population, income or other features. To improve the overall score, the project team will need to address the neighbourhoods with the lowest scores.

The assessment requires the following information to be identified and collected:

— Project design plans.

— Neighbourhood and urban plans with identification of housing typologies.

The indicator is evaluated according to the questions and the score matrix provided in Table 176.

Table 176. I.5.1 score.

Contextual variance: *Does the neighbourhood provide a variation of housing typologies? (single selection allowed)*			
a. Limited mix (clear dominance of one typology). b. Some mix (significant presence of at least two typologies, one of which is multifamily housing). c. Substantial mix (significant presence of three or more housing typologies).			
Metric: *How does the project affect the housing typology mix of the neighbourhood? (single selection allowed)*			
1. It decreases the typology mix. 2. It maintains the typology mix. 3. It increases the typology mix.			
Indicator score	**[1]**	**[2]**	**[3]**
[a]	0	45	100
[b]	20	55	85
[c]	35	65	70

Source: JRC.

Figure 124 shows the indicator thresholds used to link indicator scores with performance classes for I.5.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 124. I.5.1 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
I.5.1 thresholds ($t_{I.5.1}$):	0 ≤	$t_{I.5.1, Acceptable}$ ≥ 40	$t_{I.5.1, Good}$ ≥ 60	$t_{I.5.1, Excellent}$ ≥ 80 ≤ 100

Source: JRC.

5.8.3 Prevention of segregation at the micro-scale (I.5.2)

Indicator I.5.2 applies only to **building** and **neighbourhood-scale projects** of **residential** use, within **wealthy** or **gentrified** neighbourhoods.

In wealthier, high-income and/or gentrified areas and neighbourhoods, desegregation actions must be complemented by measures that guarantee the provision of services and amenities (Section 5.6.6) for new residents and avoid social separations in spatial proximity. The concentration of the wealthiest in specific buildings, or within the same building, the planned organisation of social differences between different floors of the building with marked differences in living quality (Maloutas and Karadimitriou, 2022), the differentiation of access, with possible consequences in terms of exclusion (Ansaloni and Tedeschi, 2016), must be countered at every scale of the project.

Neighbourhoods are defined as *wealthy* or *gentrified* when at least one of the following conditions apply:

- The average household income in the neighbourhood is above the average at the urban level.
- The housing rents/prices in the neighbourhood are above the average at the urban level.
- There is a significant gap between the minimum and maximum prices of housing (newly high value neighbourhood with a presence of low-income or vulnerable people).

Measures to mitigate the potential impacts on new residents of a new affordable housing project in a wealthy, high-income neighbourhood, or an already gentrified area include:

- Project plans that avoid clear separations in relation to the household socio-economic status.
- Project design that ensures equal construction quality in every part of the building or in all buildings (in the case of neighbourhood), regardless of the socio-economic condition of the residents.
- Plans to integrate or adapt existing services to the needs of new residents (for projects at the neighbourhood), based on purchasing power and the analysis of needs.

The assessment requires the following information to be identified and collected:

- Project design plans.
- Project plan for the allocation of housing units.
- Project strategy for services and amenities.
- Data on average income.

The evaluation of I.5.2 depends on the prevailing economic status and evolution trend within the neighbourhood, according to Table 177.

Table 177. I.5.2 score.

Metric: *If [the neighbourhood is wealthy or gentrified][1], does the project adopt any form of prevention against segregation at the micro-scale? (single selection allowed)*			
1. Preventive measures are not adopted. 2. The project is included within a neighbourhood strategy for social mix, which includes service provision, and measures are implemented at the neighbourhood level to prevent segregation, exclusion, or displacement. 3. The project includes services for the new residents and/or in its design attention is paid to not discriminate among residents.			
Indicator score	**[1]**	**[2]**	**[3]**
	0	85	100

[1] A neighbourhood is defined as wealthy/gentrified according to Section 5.8.3.

Source: JRC.

Figure 125 shows the indicator thresholds used to link indicator scores with performance classes for I.5.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 125. I.5.2 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.5.2 thresholds ($t_{I.5.2}$):	0 ≤		$t_{I.5.2, Acceptable}$ ≥ 40		$t_{I.5.2, Good}$ ≥ 60		$t_{I.5.2, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.8.4 Prevention of gentrification and displacement (I.5.3)

Indicator I.5.3 applies only to **neighbourhood-scale projects**, within **low to middle-income** or **gentrifying** neighbourhoods.

In low to middle-income neighbourhoods, desegregation efforts should be designed in ways that guarantee the prevention of gentrification and expulsion or displacement of residents. These efforts can be part of a municipal anti-gentrification strategy aiming to protect residents from displacement and local businesses from rent increases, managing tourism (where needed), limiting public space privatisation, etc.

A neighbourhood is defined as *low to middle-income* or *gentrifying* when at least one of the following conditions apply:

— The average household income in the neighbourhood is below the average at the urban level.

— There is a gentrification trend (housing costs – rents and prices – have been on the rise in the last three years).

A local comprehensive strategy for preventing gentrification and displacement must include at least the following measures:

— Community consultation processes.

— Introduction of rent controls.

— Regulation of tourist accommodations.

— Protection of local businesses (for diversity and affordability).

— Provision of legal assistance against evictions.

The assessment requires the following information to be identified and collected:

— Project plan for the allocation of housing units.

— Information about local real estate market for the last three years.

— Data on average income.

The evaluation of I.5.3 depends on the prevailing economic status and evolution trend within the neighbourhood, according to Table 178.

Indicator I.5.3 does not penalise projects that cannot count on a local strategy, if they adopt ad hoc measures.

Table 178. I.5.3 score.

Contextual variance: *If [the neighbourhood is low to middle-income or gentrifying][1], which of the following trends is identified within the scale of the project (i.e. neighbourhood)? (single selection allowed)*			
a. Steep increase (≥ 10%) of housing costs (rents and prices) in the neighbourhood in the last three years. b. Average increase (≥ 3% and < 10%) of housing costs (rents and prices) in the neighbourhood in the last three years. c. Stable or minimal variation (< 3%) of housing costs (rents and prices).			
Metric: *If [the neighbourhood is low to middle-income or gentrifying], does the project adopt any form of prevention against gentrification and displacement? (single selection allowed)*			
1. Preventive measures are not adopted. 2. Some measures are taken at the project level, but a local comprehensive strategy is not adopted. 3. The project is included within a neighbourhood or municipal housing policy for the protection of residents from price increases and displacement, or the project provides ad hoc measures.			
Indicator score	**[1]**	**[2]**	**[3]**
[a]	0	50	100

[b]	20	65	90
[c]	35	75	85

[1] A neighbourhood is defined as low to -middle-income or gentrifying according to Section 5.8.4.

Source: JRC.

Figure 126 shows the indicator thresholds used to link indicator scores with performance classes for I.5.3. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 126. I.5.3 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.5.3 thresholds ($t_{I.5.3}$):	0 ≤		$t_{I.5.3, Acceptable}$ ≥ 40		$t_{I.5.3, Good}$ ≥ 60		$t_{I.5.3, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.8.5 Outreach activities for project-related social and cultural services (I.5.4)

Indicator I.5.4 applies only to **building** and **neighbourhood-scale projects**.

Outreach is necessary to ensure the involvement and participation of individuals in the activities and services (Section 5.5.5) offered within the project. Participation requires that the project offers a physical space as well as organisational structures, especially a commitment to engage in outreach activities specifically targeting the hardest-to-reach, more marginalised population, typically more distant from civic or cultural practices.

Outreach may include:

— Co-design of the activity plan with local stakeholders.

— Calls for initiatives.

— Organisation of friendly collective events.

— Dedicating a space for reception with free access.

The indicator is evaluated according to the questions and the score provided in Table 179.

Residential projects (i.e. not providing any services) should assess outreach activities for the use and management of common areas.

Non-residential projects (e.g. schools, gyms, community centres, cultural centres) should select answer [1] if no outreach activities are planned; response [2] if an outreach strategy exists, but only for some of the services offered; response [3] if there is a comprehensive outreach strategy for each service offered.

The assessment requires the following information to be identified and collected:

— Project design plans.

— Project strategy for outreach activities.

Table 179. I.5.4 score.

Metric: *Are diverse outreach activities planned to spread the knowledge of and secure recruitment for existing or project-related social and cultural services? (single selection allowed)*			
1. Activities are not planned. 2. Yes, to some extent: an outreach strategy exists, but covers only some of the services offered. 3. Yes, an overall strategy is in place: a comprehensive outreach strategy exists, covering all services offered, identifying specialised target groups, methodology and communication plans for each service.			
Indicator score	**[1]**	**[2]**	**[3]**
	0	50	100

Source: JRC.

Figure 127 shows the indicator thresholds used to link indicator scores with performance classes for I.5.4. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 127. I.5.4 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.5.4 thresholds ($t_{I.5.4}$):	0 ≤		$t_{I.5.4, Acceptable}$ ≥ 40		$t_{I.5.4, Good}$ ≥ 60		$t_{I.5.4, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.8.6 Example (I.5)

A project involves the redevelopment of a brownfield site in a low to middle-income neighbourhood in a medium-sized European city with moderate real estate pressure. The project includes the construction of four residential buildings, two buildings with offices and commercial spaces, a nursery, a primary school, a multi-sports gymnasium, and green areas. Half of the housing units are designated as social housing, 15% are intended to accommodate students, and the remainder (i.e. 35%) are available at market prices.

Since the neighbourhood scale project includes mixed use, the user will need to classify the project based on the most dominant aspect and assess only this one at the scale of the complete project. Alternatively, the user may opt to assess the project as two individual projects, one addressing residential use, and one addressing non-residential use, both assessed at the scale of the complete project as follows:

Project classification – a: Neighbourhood – Newbuild – Residential

Project classification – b: Neighbourhood – Newbuild – Non-residential

The second approach is followed in the following.

Housing typology mix (I.5.1): The housing typology of the project is the multifamily housing, also characteristic of the area. The area where the project is implemented offers some housing mix: 60% of housing types are multifamily and multi-storey building, 40% are semidetached houses. Accordingly, the project globally reduces the current mix ([b-1] response in Table 176) by adding a share of buildings that reflect only one typology. Therefore, it attains a score of I.5.1a = 20. To improve the indicator score, the project team should introduce a different typology from the multi-storey apartment for at least half of the planned housing units. For non-residential use the indicator is omitted from calculations.

Prevention of segregation at the micro-scale (I.5.2): Not applicable to this project for both residential and non-residential use. The project is developed in a low to middle-income area, while I.5.2 refers to wealthy or gentrified neighbourhoods. I.5.2 is not applied to non-residential projects.

Prevent of gentrification and displacement (I.5.3): The neighbourhood is characterised as low to middle income, and it is subject to a slow dynamic of gentrification. Housing prices have been moderately on the rise in the last three years, and rents have raised by 8%. No specific measures have been taken to prevent the worsening of gentrification and avoid the displacement of the most vulnerable segments of the population. For example, no measure has been planned to limit the possible development of tourist accommodation (for the market price housing component). Considering a [b-1] response in Table 178, the project attains a score of I.5.2a, b = 20. To improve the indicator score, the project should, in the absence of a specific municipal policy, involve a consultation process with the surrounding population and identify critical points, set a strategy for the commercial offer (e.g. shops that meet the needs of a low-income population), ensure that the market-rate housing has price and rent caps.

Outreach activities for project-related social and cultural services (I.5.4): For residential use, no outreach activities are planned for the use and management of common residential areas in residential buildings, but some outreach activities are planned for the use of the public green areas in the neighbourhood. Considering a [2] response in Table 179, the indicator attains a score of I.5.1a = 50. For non-residential use (i.e. offices and commercial spaces, nursery, primary school, gymnasium), the project aims to reach all residents of the new neighbourhood and neighbouring areas through communication campaigns both online and offline. The project further aims to organise activities open to all and to create opportunities for socialisation. A comprehensive strategy is in place ([3] response in Table 179), so the indicator attains a score of I.5.1b = 100.

The key performance indicator I.5 is calculated for the residential use as:

$$I.5a = (0.3 \cdot 20 + 0.3 \cdot 20 + 0.2 \cdot 50)/(0.3 + 0.3 + 0.2) = 27.5 \tag{259}$$

The score corresponds to a Low performance class, and a performance class score of $PCS_{I.5}$ = 10.

The key performance indicator I.5 is calculated for the non-residential use as:

$$I.5b = (0.3 \cdot 20 + 0.2 \cdot 100)/(0.3 + 0.2) = 52 \tag{260}$$

The score corresponds to an Acceptable performance class, and a performance class score of $PCS_{I.5}$ = 45.

5.9 Needs and resources for social accessibility (I.6)

5.9.1 Description and assessment

Social accessibility is about diversifying access and taking care of as well as supporting the various needs of individuals and groups in all settings. As recognised by the Urban Agenda for the EU (EU Ministers for Urban Matters, 2016), designing solutions that respond to people's needs must necessarily involve a better understanding of the context and collection of accurate data.

This endeavour can be broken down into:

— Identifying local needs and assets.

— Maximising the accessibility of everyone and mostly of target groups.

To effectively address the various arrangements and criteria by which different groups experience social inclusion or exclusion, and to identify ways to remove both obvious and hidden barriers to access in each context, it is crucial to thoroughly "understand" the target group(s) of the project. This involves recognising their specific needs, based on the profiles of the residents in the area where the project will be implemented. In addition, it is important to identify the spatial and social resources that are provided by the context (within the scale of the project) and those resources that can be leveraged by the project. It is equally important to identify potential deficiencies that can be addressed or compensated by the project. The involvement of the local community and stakeholders in building the knowledge base is a crucial element for the quality of information and its usefulness to the project.

Under the KPI Needs and resources' assessment (I.6), an assessment of the following indicators is performed:

— *Active accessibility needs in the project strategy* (I.6.1).

— *Mapping of assets and resources* (I.6.2).

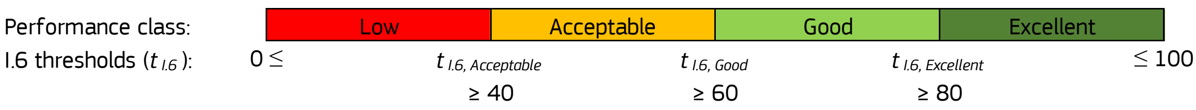
— *Diversification of activities in response to local needs* (I.6.3).

In the **general case** when all indicators apply (Table 155), the score of key performance indicator I.6 is evaluated according to Equation (261). Indicator I.6.3 does not apply to urban-scale projects.

$$I.6 = \sum_{j=1}^{3} \left(w_{I.6.j} \cdot I.6.j\right) \Big/ \sum_{j=1}^{3} \left(w_{I.6.j}\right) = 0.25 \cdot I.6.1 + 0.4 \cdot I.6.2 + 0.35 \cdot I.6.3 \leq 100 \tag{261}$$

Each indicator is evaluated with a score between 0-100. The performance class of the I.6 key performance indicator is assessed according to the thresholds in Figure 128.

Figure 128. I.6 performance classes and thresholds.



Source: JRC.

5.9.2 Active accessibility needs in the project strategy (I.6.1)

Indicator I.6.1 evaluates whether the project considers the needs of prospective residents and users, and their potential barriers to access the services offered by active modes. To this end, the project must analyse how its future users will reach the premises, considering both timing and modes of transportation. The analysis should include:

- Careful identification of the target group, taking into account individuals or groups facing greater (social, economic, physical) disadvantages.
- Estimation of the time for the most remote users to reach the project entry points by different modes, i.e. walking, cycling, public transport. Analysis should further include an evaluation of the public transport quality, by accessing local surveys regarding prices, frequency and punctuality of the service.
- Once potential obstacles are identified, a strategy should be devised to improve accessibility.

The assessment requires the following information to be identified and collected:

- A plan of the neighbourhood or urban area, depending on the scale of the project, where possible obstacles to movement are identified (e.g. presence of slopes, absence or insufficiency of sidewalks, dangerous crossings) or the requirement to travel on major high-traffic roads.
- Information on local transport service: lines, stops, frequency.
- Information about user evaluation of public transport (local surveys).
- Bike lanes (existing or planned).
- Analysis of needs based on user categories (for services, activities and amenities). Analysis of resident needs, in the case of projects including housing. Analyses should be based, as much as possible, on knowledge of the target group. If such knowledge is not sufficient during preliminary stages, analyses must consider the accessibility for children, elderly people, and individuals with disabilities.

The indicator is evaluated according to the questions and the score provided in Table 180.

Table 180. I.6.1 score.

Metric: *Are active accessibility needs included in the project strategy? (single selection allowed)*			
1. Active accessibility needs for offered services are not taken into account.			
2. The project partially addresses the issue of accessibility through a preliminary plan.			
3. The project includes an accessibility strategy based on the analysis of local needs.			
Indicator score	**[1]**	**[2]**	**[3]**
	0	55	100

Source: JRC.

Figure 129 shows the indicator thresholds used to link indicator scores with performance classes for I.6.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 129. I.6.1 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.6.1 thresholds ($t_{I.6.1}$):	0 ≤		$t_{I.6.1,\ Acceptable}$ ≥ 40		$t_{I.6.1,\ Good}$ ≥ 60		$t_{I.6.1,\ Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.9.3 Mapping of assets and resources (I.6.2)

The availability of quality assets and resources in a neighbourhood is crucial for the quality of life of citizens. Including in a project the analysis and mapping of existing resources, may serve as a knowledge base to promote better design solutions aligned with needs, address possible gaps and prioritise strategies.

Assets and resources must be identified at the appropriate level, i.e. at the neighbourhood for building and neighbourhood-scale projects, and at the urban level for urban-scale projects. In the latter case of urban-scale projects, the mapping also serves to highlight any concentrations of resources in certain areas and scarcity in others, to enable a more equitable and just distribution. In the case of urban scale projects, the assessment of the indicator should be performed separately for each neighbourhood. The indicator score is finally estimated as a weighted average, with weights based on neighbourhood population, income or other features.. To improve the overall score, the project team will need to address the neighbourhoods with the lowest scores.

During the project design and implementation phases, the identified resources and assets can be utilised to develop tailored and effective solutions that promote social inclusion. Such resources can be physical and human assets. Physical assets may include institutional and community spaces such as:

- Welfare spaces (day-shelters, welfare offices, legal counselling offices).
- Educational spaces (day-care centres, secondary schools, and other educational establishments).
- Cultural spaces (libraries, cultural venues, museums, etc.).
- Community spaces (community facilities and centres, youth community hubs, recreational centres, etc.).
- Sport and leisure spaces (sport facilities).
- Green and public spaces (playgrounds, parks, nature reserves, etc.).

Human assets bring knowledge and networks regarding:

- Grassroots organisations.
- Social leaders.
- Influential people and activists.
- Representatives of minorities.
- Neighbourhood or resident boards.
- Residents, etc.

A mapping of local assets and resources should be done in the project design phase and regularly updated during implementation, by involving the local community as much as possible. Projects that map assets and resources with the direct involvement of the local community are rewarded. For an overview of concepts and mapping tools see Foot and Hopkins (2010).

When a project does not involve an existing community, as in the case of a new neighbourhood, the mapping of assets should be conducted over a wider area than the project scale. The mapping should also be based on the planned physical assets and anticipated human resources involved, to assess whether these assets correspond to the needs of future residents as well as neighbouring communities.

The indicator is evaluated according to the questions and the score provided in Table 181.

Table 181. I.6.2 score.

Metric: *Are assets and resources mapped? (single selection allowed)*			
1. Mapping of assets and resources is not integrated or planned. 2. A partial preliminary mapping is included in the project without the involvement of the local community. 3. A complete mapping of assets and resources is integrated through the involvement of the local community.			
Indicator score	**[1]**	**[2]**	**[3]**
	0	50	100

Source: JRC.

Figure 130 shows the indicator thresholds used to link indicator scores with performance classes for I.6.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 130. I.6.2 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent
I.6.2 thresholds ($t_{I.6.2}$):	0 ≤	$t_{I.6.2, Acceptable}$ ≥ 40	$t_{I.6.2, Good}$ ≥ 60	$t_{I.6.2, Excellent}$ ≥ 80	≤ 100

Source: JRC.

5.9.4 Diversification of activities in response to local needs (I.6.3)

Indicator I.6.3 applies only to **building** and **neighbourhood-scale projects**.

The access to the project activities is adequately diversified when the project provides services and activities that are relevant to the target population. Similarly, the right to access is guaranteed across generations when their different needs are acknowledged. For example, when digital modalities of access are offered to younger generations together with analogic modalities — e.g. physical info points — for older generations.

A mapping of local needs concerning activities should involve residents and grassroots organisation. It serves not only to delineate the profile of the neighbourhood and its inhabitants (socio-economic, cultural, demographic, etc.) but also as a phase of engagement in the planning and design activity.

The profile of potential users and beneficiaries should be developed through the collection of disaggregated data at the neighbourhood level, meaning detailed data for relevant sub-categories such as gender, level of education, socio-economic status, ethnic group, or vulnerable category, etc. Aggregated data provide a general overview of the studied area but tend to conceal disparities and differences that may exist among subgroups, making analyses less accurate and the project less targeted. Disaggregated data at the neighbourhood level can be collected through surveys, from local institutions and grassroots organisations (see Section 5.10.1 for more details).

The indicator is evaluated according to the questions and the score provided in Table 182.

In the case of a multidimensional project, involving buildings and spaces designated for various activities and services, for which there is no comprehensive mapping but rather several mappings with varying levels of completeness and involvement of local actors, the project partially meets the criterion, and the response to be selected is number [2].

Table 182. I.6.3 score.

Metric: *Are the activities of the project adequately diversified according to local needs? (single selection allowed)*			
1. The activities of the project are planned (or will be) according to assumptions about local needs without the use of local data. 2. The activities of the project are planned (or will be) according to a mapping based on the project team's knowledge and/or some aggregated data. 3. The activities of the project are planned (or will be) according to a mapping based on the collection of disaggregated data and/or the involvement of the local community.			
Indicator score	**[1]**	**[2]**	**[3]**
	0	50	100

Source: JRC.

Figure 131 shows the indicator thresholds used to link indicator scores with performance classes for I.6.3. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 131. I.6.3 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent
I.6.3 thresholds ($t_{I.6.3}$):	0 ≤	$t_{I.6.3, Acceptable}$ ≥ 40	$t_{I.6.3, Good}$ ≥ 60	$t_{I.6.3, Excellent}$ ≥ 80	≤ 100

Source: JRC.

5.9.5 Example (I.6)

The project involves the redevelopment of a brownfield site to create two social housing buildings, a public park, and a tourist accommodation facility. The project is classified as: Neighbourhood – Newbuild – Residential.

Active accessibility needs in the project strategy (I.6.1): To ensure accessibility to the project area through active modes and reduce the impact of car use, the project has developed a preliminary plan that includes the creation of a network of bicycle lanes connecting to the existing network. Access via public transport will be addressed at a later stage. Considering a [2] response in Table 180, the indicator attains a score of I.6.1 = 55.

Mapping of assets and resources (I.6.2): A preliminary mapping has been performed in the neighbourhood, from which the project planned uses (social housing and tourism) were derived. A partial asset mapping has been delivered but no mapping of human resources has been carried out. Considering a [2] response in Table 181, the indicator attains a score of I.6.2 = 50.

Diversification of activities in response to local needs (I.6.3): Planned activities, ranging from hospitality to commercial ones, are planned based on data collected by the project team and provided partly by the municipality. Disaggregated data have not been collected. Considering a [2] response in Table 182, the indicator attains a score of I.6.3 = 50.

The key performance indicator I.6 is calculated as:

$$I.6 = 0.25 \cdot 55 + 0.4 \cdot 50 + 0.35 \cdot 50 = 51 \quad (262)$$

The score corresponds to an Acceptable performance class, and a performance class score of $PCS_{I.6}$ = 45.

5.10 Needs of vulnerable and marginalised groups (I.7)

5.10.1 Description and assessment

The key performance indicator I.7 reflects the target of social accessibility. Based on the mapping of vulnerabilities existing at the neighbourhood and urban level, it evaluates the extent to which the needs of vulnerable and marginalised individuals and groups are acknowledged by the project.

The recommended approach is to collect disaggregated data (e.g. age, sex and gender, race, ethnicity, disability, socioeconomic status, education, religion, health, language) and reaggregate or intersect them to identify the types of vulnerabilities (e.g. young single-parent women with recent immigration background, elderly homeless individual with alcohol or drug addiction) within the target group(s), for an intersectional approach to equality (Rosenfeld, 2023). Having disaggregated data is a challenge. However, for this target an accurate and detailed ex ante knowledge of the project target group(s) is paramount to achieve good results. Thus, the project teams need to show that they are aware of the issue, and they are willing to conduct a thorough needs analysis of needs based as much as possible on disaggregated data to become familiar with their target group(s).

This approach is demanding. There might be individuals or groups whose vulnerabilities are less apparent, and, thus, they may be more difficult to find and reach. In this sense, it is paramount that, especially during the ex-ante phase, the project managers reach out e.g. to local welfare and social services offices, health organisations, civil society organisations, informal citizens groups, socially active foundations, and NGOs. Reaching out aims to establish as much as possible a direct contact with individuals and groups, and more precisely identify the project target group(s) and their needs. Guidance on data disaggregation is provided in the IAEG-SDGs and UNSD (2021) report and UN-OHCHR (2018).

In summary, there is the need for the project to (*i*) involve an adequate number of skilled social and community workers, (*ii*) be in touch with the relevant stakeholders active in the project area and beyond, (*iii*) guarantee access across diversity, and (*iv*) ensure a safe and secure environment for all.

Indicators for this target focus on identifying groups that are potentially excluded or marginalised by the project and understanding the barriers to accessibility. It also explores measures to remove these barriers, which can be quite diverse and often invisible to designers and policymakers. Inclusive access needs here to be understood not only as a set of minimum standards of accessibility, but also involving qualitative considerations on how to make the environment more hospitable beyond those standards.

Inclusive access includes:

— Identifying the various ways in which, and criteria by which, different groups of people are in/excluded in each context, highlighting the reasons why they are in/excluded, and what can be done to remove the (in)visible barriers to access.

— Identifying the diverse ways in which the cultural, socioeconomic, normative, psychological, cognitive, and socio-emotional needs of various groups are addressed, enhanced, and duly acknowledged. These needs are intricately interconnected, and particularly for more vulnerable and marginalised individuals and groups, they must all be intersected and taken into consideration to the greatest extent possible.

Under the KPI Needs of vulnerable and marginalised groups (I.7), an assessment of the following indicators is performed:

— *Acknowledgement of cultural and social barriers to accessibility* (I.7.1).

— *Local support networks and trained social workers* (I.7.2).

— *Needs of vulnerable and marginalised groups covered by activities* (I.7.3).

In the **general case** when all indicators apply (Table 155), the score of key performance indicator I.7 is evaluated according to Equation (263). I.7.3 does not apply to urban-scale projects.

$$I.7 = \sum_{j=1}^{4}\left(w_{I.7.j} \cdot I.7.j\right) \Big/ \sum_{j=1}^{4}\left(w_{I.7.j}\right) = 0.4 \cdot I.7.1 + 0.3 \cdot I.7.2 + 0.3 \cdot I.7.3 \leq 100 \qquad (263)$$

Each indicator is evaluated with a score between 0-100. The performance class of the I.7 key performance indicator is assessed according to the thresholds in Figure 132.

Figure 132. I.7 performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.7 thresholds ($t_{I.7}$):	0 ≤		$t_{I.7, Acceptable}$ ≥ 40		$t_{I.7, Good}$ ≥ 60		$t_{I.7, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.10.2 Acknowledgement of cultural and social barriers to accessibility (I.7.1)

If the project aims to promote social inclusion, it is essential that it identifies the barriers across various dimensions (cultural, socioeconomic, normative, psychological, cognitive, socio-emotional) that hinder or limit the proper and fair satisfaction from the built environment, especially if vulnerable and marginalised individuals or groups are concerned. Cultural and social barriers to accessibility are those material or immaterial circumstances that might hamper or prevent individuals from achieving their goals and carrying out their activities in daily life in the built environment. Circumstances can vary from one individual to another, based on their capacities, abilities and knowledge.

To identify the barriers that vulnerable individuals may encounter in accessing the built environment, an intersectional approach that leaves no one behind is encouraged. Intersectional analysis is a lens through which to look at the multiple forms of exclusions that people may experience. Depending on the context and project objectives, the analysis should be conducted through a co-production process involving all relevant stakeholders (local welfare and social services offices, health organisations, civil society organisations, informal citizen groups, socially active foundations, NGOs, etc.).

Co-production processes should support the recognition of the multiple levels at which social exclusion is materialised, by answering at least to the following questions:

— What are the barriers that prevent people with intersecting experiences of discrimination (by age, gender, ethnicity, etc.) from accessing local services?

— What are the barriers that prevent people with limited resources (economic, educational, social, cultural, etc.) from accessing essential services?

— How well does the existing services meet the needs of the least advantaged?

— To what extent are barriers to action and disempowering circumstances mitigated and addressed?

There is no exhaustive list of cultural and social barriers that can be drawn up, because the variety of possible vulnerabilities is very broad. It is suggested to identify barriers starting from the presence of vulnerable and marginalised groups or individuals in the project area (e.g. homeless people, people with addiction or mental health issues, Roma people, refugees, undocumented migrants), and consider the intersections that may increase the possibilities of exclusion. Below are some examples of most common types of barriers:

- Information barriers, due to poor language skills or information gaps.
- Procedural and administrative barriers, e.g. for homeless people or undocumented migrants (see the example of inclusive libraries in Forrest, 2022).
- Organisational barriers, such as opening hours of services that are not adjusted to users' working hours, especially vulnerable individuals (e.g. single-parent women), or due to the lack of culturally adequate spaces that acknowledge different cultural norms (see also Section 4.10).

Indicator I.7.1 must be measured in relation to the level of precariousness of the project context: the higher the level of precariousness of the existing population, the greater the need for a thorough analysis of existing barriers to inclusion. Deprivation and poverty are measured differently depending on the European country, especially at the local scale, when it comes to classifying neighbourhoods according to quantifiable criteria (Córdoba Hernández et al., 2018). For the NEB self-assessment method, a comprehensive evaluation is not required, but it is suggested to compare the percentage of the vulnerable population (such as homeless people, undocumented migrants, people with mental health problems and/or addictions, and unemployed people) in the project area with the relevant percentage in a broader area, which depends on the project scale. For building and neighbourhood-scale projects, the context at the neighbourhood level needs to be assessed and compared with the urban level. For urban-scale projects, the context must be evaluated at the urban level and compared with the regional level.

The assessment requires the following information to be identified and collected:

- Data and information about marginalised and vulnerable groups at the neighbourhood or urban level (from local census, public institutions, grassroots organisations).
- Mapping of the relevant stakeholders to be involved in the analysis.

The indicator is evaluated according to the questions and the score matrix provided in Table 183.

Table 183. I.7.1 score.

Contextual variance: *What is the level of existing vulnerabilities and precariousness (presence of homeless, undocumented migrants, people with mental health problems and/or addictions, unemployed people, etc.) [1]? (single selection allowed)*				
a. The percentage of vulnerable groups is above the average percentage in a broader context. b. The percentage of vulnerable groups is equal to the average percentage in a broader context. c. The percentage of vulnerable groups is below the average percentage in a broader context.				
Metric: *To what extent are cultural and social barriers to accessibility acknowledged by the project? (single selection allowed)*				
1. Cultural and social barriers to accessibility are not identified. 2. Cultural and social barriers to accessibility are identified by the project team through a desk review and based on assumed vulnerable groups in the area. 3. Cultural and social barriers to accessibility are identified by using various methods (desk review, interviews, surveys, etc.) and based on identified vulnerable groups in the area. 4. Cultural and social barriers to accessibility are identified through a co-production process involving relevant stakeholders to promote an intersectional analysis.				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
[a]	0	25	65	100
[b]	10	30	70	90
[c]	20	45	75	85

[1] For building and neighbourhood-scale projects, the percentage of vulnerable groups in the neighbourhood context should be compared with the percentage in the urban context. For urban-scale projects, the percentage in the urban context should be compared with the percentage in the regional context.

Source: JRC.

Figure 133 shows the indicator thresholds used to link indicator scores with performance classes for I.7.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 133. I.7.1 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent	
I.7.1 thresholds ($t_{I.7.1}$):	0 ≤	$t_{I.7.1, Acceptable}$ ≥ 40	$t_{I.7.1, Good}$ ≥ 60	$t_{I.7.1, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.10.3 Local support networks and trained social workers (I.7.2)

Some challenging contexts may require from the project to involve an adequate number of skilled social and community workers, and/or be in touch with active stakeholders in the area that can cover some social needs.

The presence of socially skilled workers within the project is of the utmost importance to achieve social accessibility goals. Workers may be both people hired ad hoc by the project and people working in socially relevant fields already active in the project area. Their presence is critical in areas characterised by marginality and precariousness, however, there is no recommended benchmark for the ratio of social service workforce to a given population and no quality standards globally recognised (UNICEF, 2022).

Equally important is that civil society organisations (including informal groups), socially active foundations, religious organisations, and NGOs that are relevant to the topic of the project and work with vulnerable and marginalised individuals are involved in the project.

The assessment requires the data and information about marginalised and vulnerable groups at the neighbourhood or urban level (from local census, public institutions, grassroots organisations).

Indicator I.7.2 is evaluated according to the questions and the score matrix provided in Table 184. Projects that despite the challenging context choose not to offer support, through neither social workers nor local support networks, are penalised.

Table 184. I.7.2 score.

Contextual variance: *Considering the level of existing vulnerabilities and precariousness (presence of homeless, undocumented migrants, people with mental health problems and/or addictions, unemployed people, etc.), what is the need for support networks? (single selection allowed)*		
a. Very high need for support networks: when the percentage of vulnerable groups is much above the average percentage in a broader context[1]. b. High need for support networks: when the percentage of vulnerable groups is above the average percentage in a broader context[1]. c. Moderate/low need for support networks: when the percentage of vulnerable groups is equal to or below the average percentage in a broader context[1].		
Metric: *Does the project involve local support networks or trained social workers? (single selection allowed)*		
1. The project does not employ trained social workers and does not involve any existing local support networks. 2. The project acknowledges the importance of relying on qualified assistance through the employment of trained workers, or the use of a local support network, or both.		
Indicator score	**[1]**	**[2]**
[a]	0	100
[b]	30	90
[c]	50	85

[1] For building and neighbourhood-scale projects, the percentage of vulnerable groups in the neighbourhood context should be compared with the percentage in the urban context. For urban-scale projects, the percentage in the urban context should be compared with the percentage in the regional context.

Source: JRC.

Figure 134 shows the indicator thresholds used to link indicator scores with performance classes for I.7.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 134. I.7.2 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent	
I.7.2 thresholds ($t_{I.7.2}$):	0 ≤	$t_{I.7.2, Acceptable}$ ≥ 40	$t_{I.7.2, Good}$ ≥ 60	$t_{I.7.2, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.10.4 Needs of vulnerable and marginalised groups covered by activities (I.7.3)

Indicator I.7.3 applies only to **building** and **neighbourhood-scale projects**.

When a project plans to offer a service to the community (a community hub, a day-shelter, a cultural venue, a sport facility, a common space within a residential building, etc.), it should provide inclusive programmes to facilitate the socio-emotional bonding, considering the target users and the type of planned activities.

This objective translates into the consideration of the actual needs of vulnerable or marginalised groups and individuals from the local community in the planning of activities.

To properly address the needs of vulnerable populations, it is necessary to adopt a knowledge-based approach during the design phase, which includes data collection through an intersectional approach and mapping of such needs. In fact, the mapping of vulnerable and marginalised group needs is the preliminary step for a project to fairly address them. Such an approach is always rewarded by a high score, regardless of contextual conditions. The VulnerABLE project (ICF Consulting Services et al., 2017) provides comprehensive guidance on how to acknowledge people needs and address them from a health perspective.

The assessment requires the following information to be identified and collected:

— Data and information about marginalised and vulnerable groups at the neighbourhood or urban level (from local census, public institutions, grassroots organisations).

— Mapping of the relevant stakeholders to be involved in the analysis.

The indicator is evaluated according to the questions and the score matrix provided in Table 185.

Table 185. I.7.3 score.

Contextual variance: *What is the level of existing vulnerabilities and precariousness (presence of homeless, undocumented migrants, people with mental health problems and/or addictions, unemployed people, etc..)[1]? (single selection allowed)*				
a. The percentage of vulnerable groups is above the average percentage in a broader context. b. The percentage of vulnerable groups is equal to the average percentage in a broader context. c. The percentage of vulnerable groups is below the average percentage in a broader context.				
Metric: *Are the needs of vulnerable and marginalised groups targeted and covered by planned activities? (single selection allowed)*				
1. Needs of vulnerable groups are not specifically targeted and activities are open to all. 2. Needs of vulnerable groups are in part covered by the project activities. 3. Needs of vulnerable groups are in part covered by the project activities and for the remainder by other targeted local services. 4. Needs of vulnerable groups are totally covered by the project activities.				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
[a]	0	30	90	100
[b]	10	45	80	100
[c]	30	65	80	90

[1] For building and neighbourhood-scale projects, the percentage of vulnerable groups in the neighbourhood context should be compared with the percentage in the urban context. For urban-scale projects, the percentage in the urban context should be compared with the percentage in the regional context.

Source: JRC.

Figure 135 shows the indicator thresholds used to link indicator scores with performance classes for I.7.3. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 135. I.7.3 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent	
I.7.3 thresholds ($t_{I.7.3}$):	$0 \leq$	$t_{I.7.3, Acceptable} \geq 40$	$t_{I.7.3, Good} \geq 60$	$t_{I.7.3, Excellent} \geq 80$		≤ 100

Source: JRC.

5.10.5 Example (I.7)

A project involves the construction of residential buildings with ground-floor shops, a cultural centre in a separate building, and an office building in a medium-sized city. Since the neighbourhood scale project includes mixed use, the user will need to classify the project based on the most dominant use and assess only this one at the scale of the complete project. Alternatively, the user may opt to assess the project as two individual projects, one addressing residential use, and one addressing non-residential use, both assessed at the scale of the complete project as follows:

Project classification – a: Neighbourhood – Newbuild – Residential

Project classification – b: Neighbourhood – Newbuild – Non-residential

I.7 aims to assess the extent to which the project recognises and covers through its design the needs of marginal and vulnerable people through provided services. In this context, irrespective of assessing only residential use, only non-residential use, or both as separate projects, the score of I.7 should always be the same (i.e. I.7a = I.7b).

The neighbourhood will host low-income families, and some housing units will be allocated to refugee families and asylum seekers. Compared to the urban area, the redeveloped neighbourhood will be characterised by a higher percentage of socioeconomically disadvantaged resident population.

Acknowledgment of cultural and social barriers to accessibility (I.7.1): A thorough analysis of potential cultural and social barriers to accessibility was conducted for the activities of the cultural centre. The analysis was based on expected potential users and future residents, including individuals at risk of marginalisation due to socio-economic conditions and ethnic background. Considering a [a-2] response in Table 183, the indicator attains a score of I.7.1 = 25.

Local support networks and trained social workers (I.7.2): The involvement of social actors from the municipality is planned for the activities of the cultural centre and for raising awareness among the most disadvantaged individuals and families. Considering a [b-2] response in Table 184, the indicator attains a score of I.7.2 = 90.

Needs of vulnerable and marginalised groups covered by activities (I.7.3): The cultural needs of the new neighbourhood, especially those related to the presence of refugees and asylum seekers, will be analysed during the design phase, and fully covered by the project. Other needs, such as administrative, social, or medical support, are covered by municipal services. Considering a [a-3] response in Table 185, the indicator attains a score of I.7.2 = 90.

The key performance indicator I.7 is calculated as:

$$I.7 = 0.4 \cdot 25 + 0.3 \cdot 90 + 0.3 \cdot 90 = 64 \quad (264)$$

The score corresponds to a Good performance class, and a performance class score of $PCS_{I.7}$ = 75.

5.11 Anti-discrimination initiatives (I.8)

5.11.1 Description and assessment

The New European Bauhaus aspires for communities where people are respectful towards diversity, and groups from different backgrounds and circumstances intermingle. In different places (e.g. at work, in schools, community centres, public spaces, neighbourhood) of such communities, strong and positive relationships should be developed, regardless of background and circumstances. All citizens should have equal access to different life opportunities according to their needs and abilities; hate crime, discrimination, and harassment should be explicitly fought (by local authorities and residents).

The key performance indicator assesses the extent to which the project supports diversity, and stigmatising and excluding approaches are singled out and mitigated. Also, supporting diversity entails that the different types of knowledge emerging from citizens are adequately encouraged and connected, and people's agency is fostered.

An important role in any inclusive accessibility process is also played by the context, for example, by the presence of an appropriate and operational welfare system, or the presence of policies focusing on and fostering social inclusion. A segregated or particularly violent neighbourhood may also affect the ways in which a project is successfully implemented. If a positive, supportive, and anti-discriminatory environment is lacking — an issue that can arise due to the nature of the location rather than the project itself — then the project must demonstrate how it intends to address and compensate for this deficiency. In certain contexts and circumstances, fostering a culture of diversity and non-discrimination may require extensive, long-term efforts. This is especially true in areas where social welfare policies are limited or non-existent, or where mutual respect for diversity is neither widespread nor actively promoted by the local government. The project should recognise these challenges and be prepared to address them accordingly.

This key performance indicator aims to evaluate:

- Regarding strategies against discrimination, the commitment of projects to discourage and prevent discrimination.
- Regarding community social cohesion, the access to opportunities of collective life that encourage co-designing and co-producing across diversity (agency, sociability).

When in the project area underlying tensions exist, the project should demonstrate that the existence of possible risks for discriminating acts is acknowledged and countermeasures are taken.

Under the KPI Anti-discrimination initiatives (I.8), an assessment of the following indicators is performed:

- *Anti-discriminatory action* (I.8.1).
- *Monitoring plan of safety and non-discrimination conditions* (I.8.2).

In the **general case** when all indicators apply (Table 155), the score of key performance indicator I.8 is evaluated according to Equation (265). I.8.1 does not apply to urban-scale projects.

$$I.8 = \sum_{j=1}^{2}(w_{I.8.j} \cdot I.8.j) \Big/ \sum_{j=1}^{2}(w_{I.8.j}) = 0.65 \cdot I.8.1 + 0.35 \cdot I.8.2 \leq 100 \tag{265}$$

Each indicator is evaluated with a score between 0-100. The performance class of the I.8 key performance indicator is assessed according to the thresholds in Figure 136.

Figure 136. I.8 performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent	
I.8 thresholds ($t_{I.8}$):	0 ≤	$t_{I.8, Acceptable}$ ≥ 40	$t_{I.8, Good}$ ≥ 60	$t_{I.8, Excellent}$ ≥ 80	≤ 100

Source: JRC.

5.11.2 Anti-discriminatory action (I.8.1)

Indicator I.8.1 applies only to **building** and **neighbourhood-scale** projects.

If the context indicates that the neighbourhood (integrating the building-scale project or coinciding with the neighbourhood-scale project) is especially conflictual and discriminatory, the project should demonstrate explicit actions against discriminatory behaviour.

A neighbourhood is conflictual when at least one of the following circumstances apply:

- Discriminatory episodes occur on a regular basis.
- Tension between people from different backgrounds and circumstances living in the neighbourhood is common and tangible in the urban everyday life.

— Some groups are excluded in different places (e.g. at work, in schools, community centres, public spaces, in the neighbourhood).

— Within the neighbourhood spaces some groups are visibly separated, and people from different backgrounds and circumstances do not mix.

Anti-discrimination action can include:

— Communication campaigns promoting a positive and welcoming attitude towards specific marginalised groups (e.g. Roma people, migrants).

— Sharing an anti-discrimination and anti-harassment policy abide by everyone with access to the project.

— Organising workshops and training sessions on discrimination and advocacy for the project stakeholders and partners.

— Designing welcoming spaces that prevent stigmatisation and build supportive environments for diversity (Hodgetts et al., 2008).

Indicator I.8.1 is evaluated according to the questions and the score matrix provided in Table 186.

Table 186. I.8.1 score.

Contextual variance: *To your knowledge, can the neighbourhood be described as conflictual? (single selection allowed)*

a. If [Renovation project] has been selected – Yes: e.g. discriminatory episodes on regular basis; tensions among neighbours or residents that affect daily life; specific social groups excluded by public or common spaces; social groups with no mixing in public spaces or public spaces like schools, community centres, public services).

b. If [Renovation project] has been selected – Yes, to some extent: there is respect towards diversity, and positive relationships are being developed, even though discriminatory episodes may occasionally occur in different places, e.g. public spaces, schools, community centres, public services).

c. If [Renovation project] has been selected – No: people are usually respectful towards diversity, and groups from different backgrounds and circumstances intermingle and build strong and positive relationships in different places.

d. If [Newbuild project] has been selected, check the metric below.

Metric: *Does the project plan anti-discriminatory action? (single selection allowed)*

1. Such action is not planned.
2. Such action is not necessary at the project scale because it is sufficiently developed at a higher level by public authorities, and the users are knowledgeable about it.
3. Such action is not necessary at the project level, but it is planned as an important issue.
4. Such action is necessary, and it is implemented at the project level.
5. Such action is planned (irrespective of context).

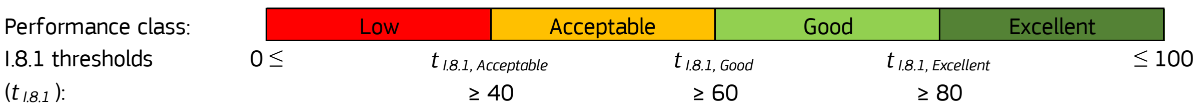
Indicator score[1]	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
[a]	0	65	—	100	—
[b]	0	65	—	100	—
[c]	50	85	100	—	—
[d]	0	—	—	—	100

[1] Dashes correspond to options that cannot be selected by the user, given the contextual variance.

Source: JRC.

Figure 137 shows the indicator thresholds used to link indicator scores with performance classes for I.8.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 137. I.8.1 indicative performance classes and thresholds.



Source: JRC.

5.11.3 Monitoring plan of safety and non-discrimination conditions (I.8.2)

In every context, but especially in precarious and deprived ones, the project should monitor safety and non-discrimination conditions over time.

Safety here refers to the perception of insecurity, fear, and discomfort in the built environment, particularly among vulnerable groups such as women, girls, LGBTQ+ individuals, and marginalised communities (e.g., Roma people, other ethnic communities). This perception, which can result from design and planning that do not consider the needs of these vulnerable individuals, can lead to restricted access to the built environment and the resources and opportunities available (ARUP, 2022). For example, poor lighting in outdoor areas or along pathways can reduce women's mobility, while overly controlled spaces can limit the access of undocumented or homeless people (Hodgetts et al., 2008).

Measures for the monitoring of safety and non-discrimination conditions may include:

— Ad hoc informational events, courses and/or learning material on non-discrimination.

— Cyclical monitoring of safety and non-discrimination conditions in the places where activities are carried out (UN-Habitat, 2023).

— Specific policy devoted to guarantee and support safety needs of vulnerable individuals and groups within the premises of the building (UN-Women, 2019).

In the case of urban scale projects, the assessment of the indicator should be performed separately for each included neighbourhood. The indicator score is finally estimated as a weighted average, with weights based on neighbourhood population, income or other features. To improve the overall score, the project team will need to address the neighbourhoods with the lowest scores.

The indicator is evaluated according to the questions and the score provided in Table 187.

Table 187. I.8.2 score.

Metric: *Does the project include a monitoring plan of safety and non-discrimination conditions of the places where activities are carried out? (single selection allowed)*			
1. A monitoring plan is not included. 2. A monitoring plan is not elaborated but some measures are planned. 3. Yes, a monitoring plan is included.			
Indicator score	**[1]**	**[2]**	**[3]**
	0	55	100

Source: JRC.

Figure 138 shows the indicator thresholds used to link indicator scores with performance classes for I.8.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 138. I.8.2 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
I.8.2 thresholds ($t_{I.8.2}$):	$0 \leq$	$t_{I.8.2, Acceptable} \geq 40$	$t_{I.8.2, Good} \geq 60$	$t_{I.8.2, Excellent} \geq 80$; ≤ 100

Source: JRC.

5.11.4 Example (I.8)

The example project of Section 5.10.5 is employed here to evaluate anti-discrimination initiatives. Similarly to the I.7 evaluation, irrespective of assessing only residential use, or only non-residential use, or both as separate projects, the score of I.8 should always be the same (i.e. I.8a = I.8b).

Anti-discriminatory action (I.8.1): The project does not include any anti-discrimination preventive strategy. Since it is a new neighbourhood, the indicator score is I.8.1 = 0 ([d-1] response in Table 186).

Monitoring plan of safety and non-discrimination conditions (I.8.2): A monitoring plan for safety and non-discrimination needs is not present but some measures are planned (for example, dissemination of learning material). The indicator score is I.8.2 = 55 ([2] response in Table 187).

The key performance indicator I.8 is calculated as:

$$I.8 = 0.65 \cdot 0 + 0.35 \cdot 55 = 19.3 \qquad (266)$$

The score corresponds to a Low performance class, and a performance class score of $PCS_{I.8}$ = 10.

5.12 Involvement of stakeholders (I.9)

5.12.1 Description and assessment

The key performance indicator I.9 aims at assessing the involvement and contribution of different stakeholders in the design and implementation process of projects.

Participatory, pro-democratic tools facilitate the access to information to the public, as wells as its effective participation in shaping public policies via multilevel and co-creation processes. The past decades have seen a rising concern in embracing public opinions in the design phase of several public policies. Moreover, there is a general agreement on the advantages of a bottom-up, multi-level, and place-based approach when implementing public policies, strategies, programmes, and projects (COM, 2001; Lawn, 2006; Marginson and Keune, 2015; Oberthür, 2019).

The involvement of citizens in a project depends on the level of information and the consultation process/tools, which can include: (*i*) public meetings or large stakeholder events, (*ii*) stakeholder and expert workshops, (*iii*) deliberative interviews, (*iv*) reflection forums, (*v*) focus groups, (*vi*) targeted questionnaires, and (*vii*) political consultation.

Bottom-up participatory approaches are critical to promote awareness and acceptance, as well as to capture the diversity of needs and perceptions from involved stakeholders (van den Hove, 2006).

The complex know-how of project and programme management in connection with the New European Bauhaus brings together actors with various knowledge and skills and their levels. Therefore, the forms of their involvement vary, from delegation of powers to other stakeholders, to a consultative way of acting (Polverari et al., 2022). To successfully include stakeholders, they must be willing and capable to provide some structure, tools, knowledge, resources, compliance, ideas and creativity, or legitimacy to the projects (Hager and Brudney, 2011; Haski-Leventhal et al., 2018; Loeffler and Bovaird, 2016).

The first aspect to consider is the existing stakeholder environment and the strengths of networks. In this context, it is useful to consider the following questions to determine which stakeholders have access to the design and implementation processes of the project. Questions to consider can include (based on van der Zwet and Ferry, 2019):

- Who provides input into the design process?
- What is the balance between the involvement of grassroot actors and professionals?
- What is the territorial coverage of the actors involved?
- What is the level of participation of communities and residents?
- What measures have been taken to involve hard-to-reach groups in the project design phase?

This key performance indicator I.9 aims to measure:

- The level of involvement of stakeholders in the project design process.
- The level of contribution of stakeholders to the outcomes of the project design process.
- The level of inclusiveness of hard-to-reach and easy-to-overlook groups, especially vulnerable and marginalised groups.
- The resources available for the implementation of the participatory process.

Under the KPI Involvement of stakeholders (I.9), an assessment of the following indicators is performed:

- *Involvement of local stakeholders in project meetings* (I.9.1).

— *Involvement of public and private sector stakeholders in project meetings* (I.9.2).

— *Contribution of local civil society stakeholders to project design* (I.9.3).

— *Contribution of public and private sector stakeholders to project design* (I.9.4).

— *Diversity and representativeness of the stakeholders in project design* (I.9.5).

— *Contribution of stakeholders from vulnerable groups to project design* (I.9.6).

— *Project budget allocated to engagement events* (I.9.7).

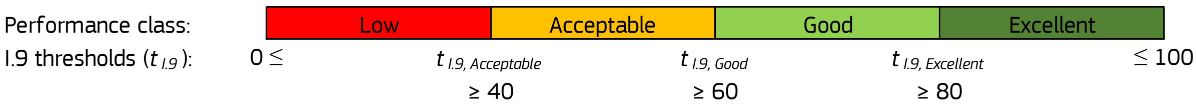
The level of involvement and the level of contribution of stakeholders in the design of a project are certainly related but not interchangeable. A highly involved stakeholder indicates a robust participatory procedure, especially if different types of stakeholders are actively and regularly involved. The high involvement does not necessarily lead to the stakeholder's significant contribution to the design of a project. Measuring involvement evaluates the adoption of democratic-inclusive procedures; measuring contribution evaluates the effectiveness of such procedures. This measurement is calibrated taking into account the profile of stakeholders involved.

The score of key performance indicator I.9 is evaluated according to Equation (267).

$$I.9 = \sum_{j=1}^{7}\left(w_{I.9.j} \cdot I.9.j\right) \Big/ \sum_{j=1}^{7}\left(w_{I.9.j}\right) = 0.18 \cdot I.9.1 + 0.10 \cdot I.9.2 + 0.20 \cdot I.9.3 + 0.10 \cdot I.9.4 + 0.12 \cdot I.9.5 + 0.18 \cdot I.9.6 + 0.12 \cdot I.9.7 \leq 100 \quad (267)$$

Each indicator is evaluated with a score between 0-100. The performance class of the I.9 key performance indicator is assessed according to the thresholds in Figure 139.

Figure 139. I.9 performance classes and thresholds.



Source: JRC.

5.12.2 Involvement of local stakeholders in project meetings (I.9.1)

Different stakeholders can have a different level of involvement in the design of projects. Indicator I.9.1 identifies the profile of local civil society stakeholders who are more involved in the project design.

The user of the NEB self-assessment method should provide an estimate of the level of participation to project meetings and events for three profiles of local civil society stakeholders according to Table 188.

Table 188. I.9.1 score.

Metric: *Considering the following three profiles (i–iii) of local civil society stakeholders,* *i. Independent citizens, citizen initiatives, neighbourhood boards or associations.* *ii. NGOs, trade unions, other civil society organisations.* *iii. Local professionals (e.g. research community, policy experts or officials, independent experts from the economic sector).* *how would you qualify their involvement in the project participatory meetings? (single selection allowed)*					
1. Active and regular involvement of profile *ii* or *iii* of stakeholders, and occasional (or no) involvement of the other two. 2. Active and regular involvement of profiles *ii* and *iii*, and occasional (or no) involvement of profile *i*. 3. Active and regular involvement of profile *i*, and occasional (or no) involvement of profiles *ii* and *iii* of stakeholders. 4. Active and regular involvement of two out of the three profiles of stakeholders (including profile *i*), and occasional (or no) involvement of the third. 5. Active and regular involvement of the three profiles of stakeholders.					
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
	15	35	55	75	100

Source: JRC.

Figure 140 shows the indicator thresholds used to link indicator scores with performance classes for I.9.1. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 140. I.9.1 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent	
I.9.1 thresholds ($t_{I.9.1}$):	0 ≤	$t_{I.9.1, Acceptable}$ ≥ 40	$t_{I.9.1, Good}$ ≥ 60	$t_{I.9.1, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.12.3 Involvement of public and private sector stakeholders in project meetings (I.9.2)

Different stakeholders can have a different impact on the design of projects. Indicator I.9.2 identifies the profile of stakeholders representing public entities and the private corporate sector that contribute more to the design of projects.

The user of the NEB self-assessment method should provide an estimate of the level of participation to project meetings and events for three profiles of public and private sector stakeholders, according to Table 189.

Table 189. I.9.2 score.

Metric: *Considering the following three profiles (i–iii) of stakeholders:* *i. Private entities (corporate).* *ii. Public entities.* *iii. Public-private partnerships.* *how would you describe their involvement in the project participatory meetings? (single selection allowed)*				
1. An occasional (or no) involvement of all stakeholders (public, corporate and public-private partnerships). 2. An active and regular involvement of corporate entities and an occasional (or no) involvement of public entities and/or public-private partnerships. 3. An active and regular involvement of public and/or public-private partnerships and an occasional (or no) involvement of corporate entities. 4. An active and regular involvement of all stakeholders (public, corporate and public-private partnerships).				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
	10	35	70	100

Source: JRC.

Figure 141 shows the indicator thresholds used to link indicator scores with performance classes for I.9.2. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 141. I.9.2 indicative performance classes and thresholds.

Performance class:		Low	Acceptable	Good	Excellent	
I.9.2 thresholds ($t_{I.9.2}$):	0 ≤	$t_{I.9.2, Acceptable}$ ≥ 40	$t_{I.9.2, Good}$ ≥ 60	$t_{I.9.2, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.12.4 Contribution of local civil society stakeholders to project design (I.9.3)

Different local civil society stakeholders can have a different impact on the design of projects. Indicator I.9.3 identifies the profile of such stakeholders who contribute the most to the design of projects.

The user of the NEB self-assessment method should provide an estimate of the level of contribution to the project design of three profiles of local civil society stakeholders, according to Table 190.

The quality of the contribution provided by stakeholders can be defined as significant if all the following conditions apply: stakeholders are involved throughout all stages of the design process, their contribution and knowledge are acknowledged and valued, and they receive and accept a mandate to influence and shape the decision-making process.

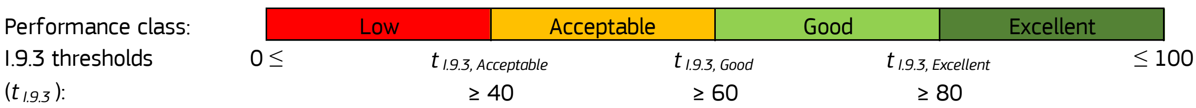
Table 190. I.9.3 score.

Metric: *Considering the following three profiles (i–iii) of local civil society stakeholders,* *i. Independent citizens, citizen initiatives, neighbourhood boards or associations.* *ii. NGOs, trade unions, other civil society organisations.* *iii. Local professionals (e.g. research community, policy experts or officials, independent experts from the economic sector).* *how would you describe their contribution to the design of the project? (single selection allowed)*						
1. No significant contribution from any stakeholder. 2. Significant contribution of profile *ii* or profile *iii* of stakeholders and minor (or no) contribution of the remaining two. 3. Significant contribution of profiles *ii* and *iii*, and minor (or no) contribution of profile *i*. 4. Significant contribution of profile *i*, and minor (or no) contribution of the remaining two profiles of stakeholders. 5. Significant contribution of two out of the three profiles of stakeholders (including *i*) and minor (or no) contribution of the third profile. 6. Significant contribution of the three profiles of stakeholders.						
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**
	0	15	35	55	75	100

Source: JRC.

Figure 142 shows the indicator thresholds used to link indicator scores with performance classes for I.9.3. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 142. I.9.3 indicative performance classes and thresholds.



Source: JRC.

5.12.5 Contribution of public and private sector stakeholders to project design (I.9.4)

Different public and private sector stakeholders can have a different impact on the design of projects. Indicator I.9.4 identifies the profile of such stakeholders contributing the most to the design of projects.

The user of the NEB self-assessment method should provide an estimate of the level of contribution to the project design of three profiles of public and private sector stakeholders, according to Table 191.

The quality of the contribution provided by stakeholders can be defined as significant if stakeholders are involved throughout all stages of the process; if their contribution and knowledge are acknowledged and valued; if they receive and accept a mandate to influence and shape the decision-making process.

Table 191. I.9.4 score.

Metric: *Considering the following three profiles (i–iii) of stakeholders:* *i. Private entities (corporate).* *ii. Public entities.* *iii. Public-private partnerships.* *how would you describe their contribution to the design of the project? (single selection allowed)*
1. No significant contribution from any profile of stakeholder. 2. Significant contribution of profile *i* or profile *ii* of stakeholders, and minor (or no) contribution of the remaining two. 3. Significant contribution of profiles *i* and *iii*, and minor (or no) contribution of profile *ii*. 4. Significant contribution of profile *ii*, and minor (or no) contribution of profiles *i* and *iii*.

5. Significant contribution of profiles *i* and *ii*, and minor (or no) contribution of profile *iii*.						
6. Significant contribution of all three profiles of stakeholders.						
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**
	0	15	35	55	75	100

Source: JRC.

Figure 143 shows the indicator thresholds used to link indicator scores with performance classes for I.9.4. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 143. I.9.4 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.9.4 thresholds ($t_{I.9.4}$):	0 ≤		$t_{I.9.4, Acceptable}$ ≥ 40		$t_{I.9.4, Good}$ ≥ 60		$t_{I.9.4, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.12.6 Diversity and representativeness of the stakeholders in project design (I.9.5)

Indicator I.9.5 evaluates the project team's ability to include a diverse range of stakeholders in the project design phase. The right participants must be involved, representing all the relevant stakeholder groups, boosting diversity of personal backgrounds and individual expertise for an optimal development of collective intelligence (Matti et al., 2022).

The diversity and variety of stakeholder groups should be evaluated considering the population that will be affected by the project and its socio-demographic composition (age, gender, ethnicity, occupation, etc.).

The identification of stakeholders through the socio-demographic composition of the population needs further elaboration considering their spatial distribution. The spatial distribution of stakeholder groups provides evidence about the overrepresentation of specific groups in the territory of the project, affecting the involvement of stakeholders in the project design. The dominant presence of a stakeholder group (e.g., elderly or Roma people) or the presence of multiple stakeholder groups in the territory of the project, differentiates the evaluation of the unilateral or diverse representation of stakeholder groups in the design of the project.

The indicator is evaluated according to the questions and the score provided in Table 192.

Table 192. I.9.5 score.

Contextual variance: *To your knowledge, how you would characterise the project context[1] in terms of significant presence of social stakeholder groups? (single selection allowed)*				
a. The context is characterised by the dominant presence of one or two stakeholder group.				
b. The context is characterised by the presence of multiple stakeholder groups.				
Metric: *How would you describe the diversity and representativeness of the stakeholder social groups involved in the design of the project? (single selection allowed)*				
1. Focused on one social group of stakeholders whose presence dominates the design phase.				
2. Mainly focused on a few social groups of stakeholders.				
3. Quite diverse and representative (most local social groups are present, only a few are missing).				
4. Very diverse and representative (all local social groups are present even if in different proportions).				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
[a]	65	75	90	100
[b]	15	45	70	90

[1] Neighbourhood context should be considered for building and neighbourhood-scale projects, and urban context for urban-scale projects.

Source: JRC.

Figure 144 shows the indicator thresholds used to link indicator scores with performance classes for I.9.5. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 144. I.9.5 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.9.5 thresholds ($t_{I.9.5}$):	0 ≤		$t_{I.9.5, Acceptable}$ ≥ 40		$t_{I.9.5, Good}$ ≥ 60		$t_{I.9.5, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.12.7 Contribution of stakeholders from vulnerable groups to project design (I.9.6)

Different stakeholders can have a different impact on the design of projects. Indicator I.9.6 identifies the profile of stakeholders that are related to vulnerable groups and contribute to the design of the project.

The user of the NEB self-assessment method should provide an estimate of the quality of the contribution of stakeholders related to vulnerable groups (e.g. homeless, refugees, individuals with disabilities, individuals under the poverty line, single-parent families, etc.) or groups with specific needs (children, teens, elderly individuals, etc.) to the design of the project.

The quality of the contribution provided by stakeholders can be defined as follows:

— Significant, if stakeholders are involved throughout all stages of the process, their contribution and knowledge are acknowledged and valued, they receive and accept a mandate to influence and shape the decision-making process.

— Fair, if stakeholders are involved throughout most stages of the process and their contribution and knowledge are acknowledged and valued.

— Rather insignificant, if the presence of the stakeholders throughout the process is irregular and not active.

The indicator is evaluated according to the questions and the score provided in Table 193.

Table 193. I.9.6 score.

Metric: *How would you describe the contribution[1] of stakeholders related to vulnerable groups to the design of the project? (single selection allowed)*				
1. No contribution. 2. Rather insignificant contribution. 3. Fair contribution. 4. Significant contribution.				
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**
	0	50	75	100

[1] Levels of contribution defined in Section 5.12.7.

Source: JRC.

Figure 145 shows the indicator thresholds used to link indicator scores with performance classes for I.9.6. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 145. I.9.6 indicative performance classes and thresholds.

Performance class:		Low		Acceptable		Good		Excellent	
I.9.6 thresholds ($t_{I.9.6}$):	0 ≤		$t_{I.9.6, Acceptable}$ ≥ 40		$t_{I.9.6, Good}$ ≥ 60		$t_{I.9.6, Excellent}$ ≥ 80		≤ 100

Source: JRC.

5.12.8 Project budget allocated to engagement events (I.9.7)

It is expected that the higher the allocated budget for the organisation of participatory events, the higher its impact on the engagement of participants in the design of the project.

The user of this tool should provide an estimate of the level of funding allocated by the project budget to events promoting the participation of different stakeholders in the design of the project.

The levels of allocated budget for participatory events as a percentage of the total budget of projects are defined as:

- Very low: < 3%.
- Low: 3–5%.
- Average: 6–8%.
- High: 9–10%.
- Very high: > 10%.

The indicator is evaluated according to the questions and the score provided in Table 194.

Table 194. I.9.7 score.

Metric: *What is the level of the project budget allocated to engagement events during the design stage? (single selection allowed)*					
1. Very low level of allocated funding (< 3%). 2. Low level of allocated funding (3–5%). 3. Average level of allocated (6–8%). 4. High level of allocated funding (9–10%). 5. Very high level of allocated funding (> 10%).					
Indicator score	**[1]**	**[2]**	**[3]**	**[4]**	**[5]**
	15	45	65	85	100

Source: JRC.

Figure 146 shows the indicator thresholds used to link indicator scores with performance classes for I.9.7. While these thresholds and performance classes are not directly applied in the evaluation of KPI and dimension scores and performance classes, they are included here to assist users in determining appropriate performance levels for specific project aspects and to offer clear guidance on their improvement.

Figure 146. I.9.7 indicative performance classes and thresholds.

Performance class:	Low	Acceptable	Good	Excellent
I.9.7 thresholds ($t_{I.9.7}$):	$0 \leq$	$t_{I.9.7, Acceptable} \geq 40$	$t_{I.9.7, Good} \geq 60$	$t_{I.9.7, Excellent} \geq 80$, ≤ 100

Source: JRC.

5.12.9 Example (I.9)

A project involves the renovation of an entire neighbourhood, consisting of 16 residential buildings, partly allocated to social housing and partly to private housing, with shared outdoor spaces, playgrounds, and parking areas. The demographic composition of the neighbourhood is diverse. In particular, the social housing units are predominantly inhabited by low-income families with a migrant background and young children. The private housing units are mostly occupied by middle-income families, with a significant presence of retirees and elderly individuals living alone. Within the neighbourhood, there is a board of resident representatives from the privately owned homes and the social housing units. Within the neighbourhood, there is a community centre, a primary school, a mosque, and a catholic church, but these are not part of the renovation project. The project involves only the retrofitting of housing buildings and the requalification of common outdoor spaces. Accordingly, the project here is classified as: Neighbourhood – Renovation – Residential. However, regardless of the user approach when a project combines multiple types and main uses (i.e. assessing the most dominant aspects or all of them as separate projects according to Section 2.3.2), the evaluation of I.9 should yield in all cases the same KPI score (i.e. in essence not affected by use and type). For example, similarly to I.8 (e.g. Section 5.11.4), evaluation of the dominant use or evaluation of both uses in a mixed-use project should yield the same results.

Involvement of local stakeholders in project meetings (I.9.1): From civil society, the project primarily involved residents, with very limited participation of some urban planning experts. No stakeholders from local organisations or associations took part in participatory meetings. Considering a [3] response in Table 188, the indicator attains a score of I.9.1 = 55.

Involvement of public and private sector stakeholders in project meetings (I.9.2): Only public local authorities took part in participatory meetings. Considering a [3] response in Table 189, the indicator attains a score of I.9.2 = 70.

Contribution of local civil society stakeholders to project design (I.9.3): Only one profile (*i*) of stakeholder (residents and their representatives) provided a significant contribution to the design process, with limited contribution by experts. Considering a [4] response in Table 190, the indicator attains a score of I.9.3 = 55.

Contribution of public and private sector stakeholders to project design (I.9.4): Only local authorities provided a significant contribution to the design process. Considering a [4] response in Table 191, the indicator attains a score of I.9.4 = 55.

Diversity and representativeness of the stakeholders in project design (I.9.5): The context is characterised by the presence of multiple stakeholder groups. However, the stakeholder group that was mainly involved in the project design consisted mainly of retired homeowners residing in a few buildings (i.e. 3 buildings out of the 16), with a smaller portion represented by parents from the social housing units. Considering a [b-1] response in Table 192, the indicator attains a score of I.9.5 = 15. To improve it, the stakeholder group should have been composed from representatives of residents following a fairer approach (proportionally to demographics) including also representatives of the school, the community centre, the church, and the mosque.

Contribution of stakeholders from vulnerable groups to project design (I.9.6): No stakeholder group related to vulnerable groups took part in the process, hence I.9.6= 0.

Project budget allocated to engagement events (I.9.7): The share of project budget allocated to engagement events is 7%. Considering a [3] response in Table 193, the indicator attains a score of I.9.7 = 75.

The key performance indicator I.9 is calculated as:

$$I.9 = 0.18 \cdot 55 + 0.10 \cdot 70 + 0.20 \cdot 55 + 0.10 \cdot 55 + 0.12 \cdot 15 + 0.18 \cdot 0 + 0.12 \cdot 75 = 44.2 \qquad (268)$$

The score corresponds to an Acceptable performance class, and a performance class score of $PCS_{I.9}$ = 45.

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List of abbreviations and definitions

Affordable housing	It refers to low-cost rental housing or access to homeownership at below market price, regardless the provider and or the administrative process (Rosenfeld, 2017).
COM	Commission communication.
D	Dimension.
De-commodification	De-commodification is the removal of the building stock from the speculative market. It occurs when in the development of the built environment public or collective ownership are adopted, and the building units/sites cannot be, or only under specific conditions, placed on the market (Fu and Velasco, 2023).
Collaborative housing	It is a complex form of ownership that includes some degree of collective or cooperative tenure; forms of collective (self)management involving dwellers; and an architectural design that promotes everyday sharing of space. Co-housing and co-living are types of collaborative housing (Griffith et al., 2024).
Financialisation	"The increasing dominance of financial actors, markets, practices, measurements, and narratives, at various scales, resulting in a structural transformation of economies, firms (including financial institutions), states, and households". It encompasses the process of transformation of range of commodities (including housing) into tradable financial assets (Aalbers, 2019).
FEANTSA	Federation European of National Organisations Working with the Homeless.
FMI	Federal Ministry of the Interior and Community (Germany).
Gentrification	Gentrification is a process of social change that involves the transition from lower to high-income residents, gradually displacing the existing lower income residents through eviction or being priced out (Davidson and Lees, 2005).
Contemporary gentrification	includes a) reinvestment of capital (by individuals, developers or the state); b) social upgrading of locale by incoming high-income groups; c) landscape change; direct or indirect displacement of low-income groups (Council of Europe, 2020).
I	Inclusiveness dimension.
IAEG-SDGs	Inter-Agency and Expert Group on SDG Indicators.
IDeA	Improvement and Development Agency
Intersectionality	"The term intersectionality references the critical insight that race, class, gender, sexuality, ethnicity, nation, ability, and age operate not as unitary, mutually exclusive entities, but as reciprocally constructing phenomena that in turn shape complex social inequalities." As such, it brings to light the multiple facets of one's personality, and, thus, helps identify and unearth not only vulnerabilities, but also, and as importantly, the various ways in which one is not only discriminated against, but also included and, thus, empowered (Collins, 2015).
Inclusive accessibility	Inclusive accessibility may broadly encompass concepts such as inclusion, diversity, equity, and accessibility. In the context of this report, we refer to it as any process of social inclusion taking place within the built environment. People are excluded from many domains of life – social, economic, political, civic and spatial – and the salience of each domain depends strongly on the country and local contexts as well as on the stage of a person's life course. That is to say, the concepts of social inclusion and social exclusion are multidimensional and context-dependent (United Nations, 2016; Zallio and Clarkson, 2021).
KPI	Key Performance Indicator.
Micro-segregation	Micro-segregation exists where individuals living in spatial proximity occupy unequal positions according to their socioeconomic status or ethno-racial identity. This might happen at the micro scale of the building, where hierarchies are distributed among floors, or within apartment blocks. Similar to neighbourhood segregation, groups with more resources have access to the best and most

	desirable dwellings and those with fewer resources are relegated to the worse quality dwelling stock (Maloutas and Karadimitriou, 2022).
NEB	New European Bauhaus.
PCS	Performance Class Score.
SFoC	Swiss Federal Office of Culture.
SDG	Sustainable Development Goals.
Social housing	It refers to the part of a housing system aimed to satisfy housing needs, supported by the State, and distributed through administrative process peculiar to every local context (UNECE, 2015).
UNDP	United Nations Development Programme.
UNECE	United Nations Economic Commission for Europe
UN-Habitat	United Nations Human Settlements Programme.
UNICEF	United Nations Children's Fund
UN-OHCHR	United Nations Human Rights Office of the High Commissioner.
UNSD	United Nations Statistics Division.
UN-Women	United Nations Entity for Gender Equality and the Empowerment of Women
w	weight.

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Chapter 6: Conclusions

6 Conclusions

Local environmental, economic, cultural, political and societal factors and their diverse evolution over time contribute to shaping distinct architectural traditions. These slowly evolving character-defining phenomena have undergone a significant acceleration in the last century, driven by novel production processes and business models, such as standardisation and large-scale manufacturing. This has led to profound changes in the landscape including the uncontrolled urban expansion of major cities and the fragmentation of spaces, offset by marginalisation, depopulation and economic stagnation of smaller towns and rural areas. These changes have exacerbated the disparities in housing conditions, fuelled gentrification and segregation and altered the engagement with the built heritage. Adding to this complexity are pressing challenges such as ageing of populations within the broader context of global population growth. Climate change, triggering more extreme weather events and more frequent natural disasters, amplifies the impact of these demographic trends, contributing to worsen resource scarcity, shift in global power balance, and migration movements.

In response, the European Union actively promotes sustainable and inclusive models, aiming to optimise resource allocation, prevent waste, reduce disaster risk, and address inequalities while enhancing health, safety, and wellbeing. Rethinking the built environment is crucial in confronting these challenges. Within this framework, the New European Bauhaus initiative is dedicated to catalysing Europe's transition towards a greener and aware society through the transformation of architecture, living spaces and experiences, guided by three dimensions: Beauty, Sustainability, and Inclusiveness. By employing a participatory and interdisciplinary co-creation approach, the New European Bauhaus aims for a paradigm shift in the conception and design of the built environment with a focus on enhancing its affordability, accessibility, circularity, resource efficiency, aesthetics, functionality and safety. The overarching ambition is to empower all projects, regardless of type, use, implementing agents, scale, and locations, to promote sustainable development, minimising environmental impact, safeguarding biodiversity, fostering community cohesion, and ultimately enhancing quality of life for all citizens.

To ensure that projects align with the core ambitions, principles, and values of the New European Bauhaus, a self-assessment method has been devised herein. The method represents an unprecedented effort to establish a comprehensive and balanced evaluation procedure, incorporating clear and measurable indicators and key performance indicators for each dimension of the New European Bauhaus. This allows all involved stakeholders to objectively evaluate the quality of their decisions and activities and determine their contribution to the New European Bauhaus goals. Indicators are integrated within key performance indicators, with values ranging from 0 to 100, enabling the quantitative assessment of specific critical targets. Following the quantitative assessment, the method further evaluates key performance indicators using descriptive terms and qualitative measures of performance (i.e. performance classes). This approach helps to handle uncertainty and mitigate the effect of employing diverse indicator formats. Key performance indicator results are aggregated applying weighting factors that prioritise the significance and impact of targets, ultimately deriving a dimension score, which in turn is translated to a performance class at the dimension level. By providing users with detailed feedback on project performance and impacts at different assessment levels, the New European Bauhaus method enables targeted improvements and enhances the likelihood of project success, reshaping living spaces in line with the New European Bauhaus objectives.

Recognising the diversity of project attributes, the key performance indicators for Sustainability, Beauty, and Inclusiveness are designed to vary in terms of scale, type, use and context to ensure a consistent and fair evaluation. This is achieved through a flexible approach intended to accommodate local characteristics and capture the specific needs of each place or project within a uniform and standardised framework. By integrating contextual variables and adjusting indicators, the adaptability and effectiveness of the method are enhanced, without compromising universality or necessitating excessive user effort.

The purpose of this handbook is to offer comprehensive guidance on the New European Bauhaus self-assessment method and its development process, providing the interested users with the necessary knowledge to conduct an effective and thorough evaluation. To this end, the handbook introduces key performance indicators, indicators, metrics, evaluation methods and measurement units. It further presents clarifying examples and supports the online tool designed to facilitate the self-assessment process. The NEB self-assessment tool is available at: https://knowledge-management.new-european-bauhaus.europa.eu/.

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