EUFORIE

European Futures for Energy Efficiency

Report. Standardization and integration of assessment methods focused on energy efficiency

Work Package 3 - Deliverable 3.4

Date: November 16th, 2018

This project is supported by the European Commission
Horizon2020 Research and Innovation Programme

www.euforie-h2020.eu

Please cite as: Ulgiati S. [1], Franzese P.P. [1], Zucaro A. [1], Fiorentino G. [1], Santagata R. [1], Corcelli F. [1], Rallo R.F. [1], Casazza M. [1], 2018. Report. Standardization and integration of assessment methods focused on energy efficiency. European Futures of Energy Efficiency (EUFORIE), Deliverable 3.4. Available at http://www.euforie-h2020.eu

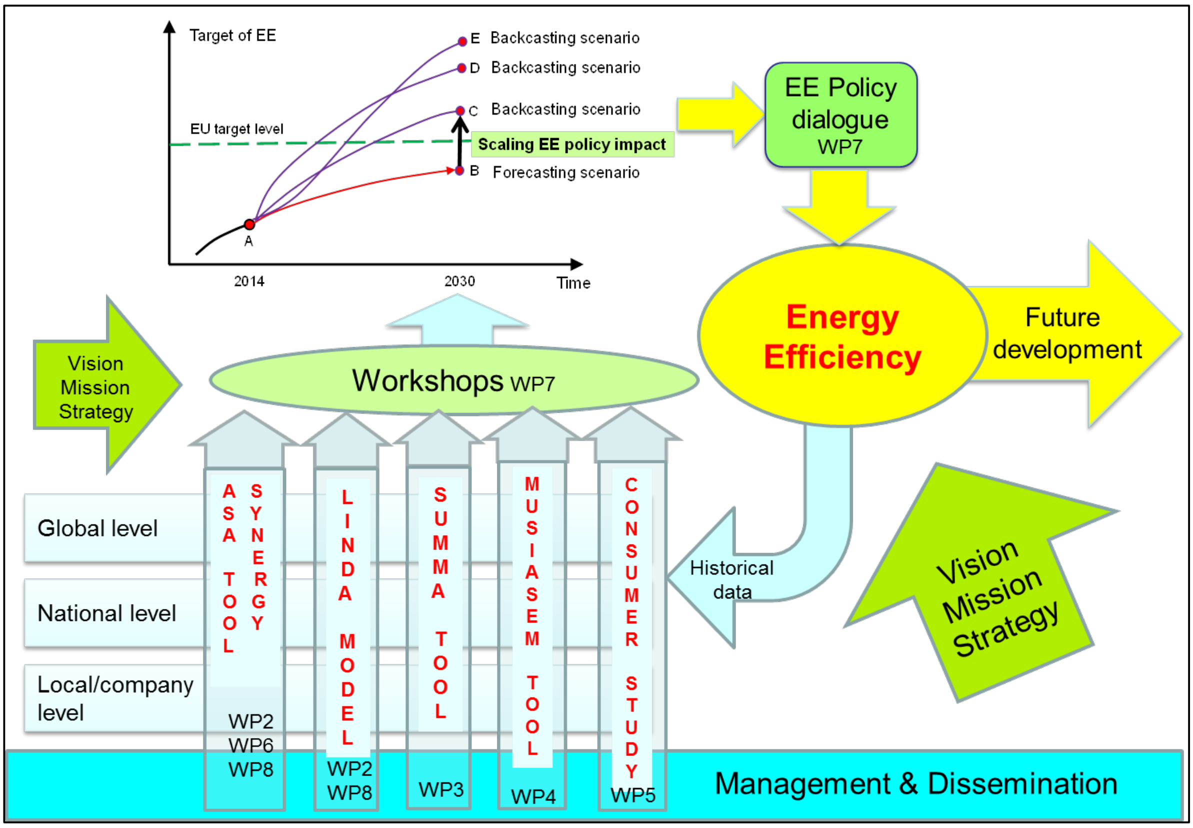
[1] Department of Science and Technology, Parthenope University Napoli, Italy

The EUFORIE project

The strategic goal of the EUFORIE project is to provide useful and accurate information and knowledge in the field of energy efficiency for the EU Commission and stakeholders in the Member States. The tangible objectives are the following:

1. To provide energy and energy efficiency trends and their drivers, synergies and trade-offs between energy efficiency related policies, as well as energy efficiency scenarios (WP2).
2. To provide data about implementation of energy efficiency in specific processes, sectors and entire systems, in order to understand bottlenecks/efficiency drops and suggest improvements (WP3).
3. To carry out analyses of efficiency of provision, from making useful energy carriers from primary energy sources, and from conversion of energy carriers to end uses across macro-economic sectors (WP4).
4. To identify policy instruments and other measures leading to significant reduction in the energy consumption of households (WP5).
5. To analyse the relationship between investments and change in energy efficiency, and to develop indicators to describe changing energy efficiency at the company level (WP6).
6. To carry out participatory foresight for European stakeholders of energy efficiency with a target of providing ideas for the energy efficiency vision and strategy in the European Union (WP7).
7. To compare energy efficiency policy instruments and measures and their impacts in China and the European Union (WP8).

The EUFORIE Work Packages relate to each other The project applies different quantitative and qualitative analysis methods to energy efficiency in the EU and its Member States at different levels and from different perspectives. These analyses provide input for foresight activities, which serve European energy efficiency vision and strategy process by generating useful information. Management (WP1) and dissemination (WP9) run in parallel with the research and innovation activities.



Target of EE
E Backcasting scenario
D Backcasting scenario
C Backcasting scenario
EU target level
Scaling EE policy impact
B Forecasting scenario
A
2014
2030
Time
EE Policy dialogue WP7
Energy Efficiency
Future development
Vision Mission Strategy
Workshops WP7
Global level
National level
Local/company level
ASA TOOL
SYNERGY
WP2 WP6 WP8
LINDA MODEL
WP2 WP8
SUMMA TOOL
WP3
MUSIASEM TOOL
WP4
CONSUMER STUDY
WP5
Historical data
Vision Mission Strategy
Management & Dissemination

Contents

Key findings and summary for stakeholders

The goal of this deliverable is to design a user-friendly prototype toolkit to allow stakeholders and policy makers to identify the main hotspots within a system/process and to draw scenarios to improve the environmental sustainability of the economic activity under investigation. The EUFORIE prototype tool, in its alpha-version, has been built in order to evaluate the environmental profitability of different levels (process, sector and system level) achievable by improving the performance of the different processes converging to the higher level. To illustrate how the EUFORIE prototype tool works for the assessment of the environmental issues, a case study representative of the system level (Napoli urban system) was selected and developed. The aim of this deliverable is to present step by step how the EUFORIE prototype tool has been designed and how input data are processed towards a final performance assessment. The procedure starts with a preliminary Life Cycle Assessment analysis (ex-ante LCA), allowing the identification of the input flows that are the main responsible of the largest impacts from the process. Once the most impacting inputs are identified, different solution scenarios are designed (Business-as-Usual, Technological Efficiency, Eco-Efficiency) and evaluated by means of the Emergy Analysis approach, in order to compare the proposed solutions based on their environmental cost. The scenario assessment and comparison is supported by a simulation program designed to help quantitative understanding of how and to what extent the assumed amount and quality variations of input flows affect the final performance indicators. Finally, an ex-post LCA is foreseen, in order to confirm if the suggested solutions have been able to solve the identified impact problems:
ex-ante LCA ==> identification of performance problems ==> simulation of Business-as-Usual, Technological and eco-Efficiency Solution Scenarios ==> ex-post LCA ==> assessment of achieved solution.

In short, the two approaches used within the EUFORIE Prototype Tool can be described as follows:
Life Cycle Assessment (LCA) stems from the basic principle that in order to accurately assess the environmental impact of a system or product, all its productive stages must be included in the analysis, “from cradle to grave‘, i.e. from resource extraction to final disposal. Several impacts are evaluated and indicators developed in order to provide a clear picture of resource use and environmental damage generated within a process or an economy. The recently published International Life Cycle Data System (ILCD) Handbook (ILCD, 2010), made available through the European Platform on LCA, further confirms the importance of LCA as a decision-supporting tool in contexts ranging from product development to policy making. The Handbook, a series of technical guidance documents to the ISO 14040-44 standards (ISO 2006a, ISO 2006b), serves as a basis for comparable and reliable LCA applications in business and public decision-making. Methodologically, a LCA is structured in four consecutive stages, namely: (i) goal and scope definition (including a clear definition of the functional unit, system boundaries and associated assumptions); (ii) life cycle inventory (the compilation of all the inputs and outputs respectively from and to nature associated to all processes that form part of the system‘s life cycle); (iii) life cycle impact assessment (in which the full inventory of inputs and outputs is translated into a number of aggregated metrics of environmental impact); and (iv) interpretation (in which results are discussed and compared to suitable benchmarks). In all cases, LCA only accounts for matter and energy flows occurring under human control, whereas flows outside of market dynamics (such as environmental services and renewable resources that do not flows through human controlled devices) as well as flows which are not associated to significant matter and energy carriers (such as labor, culture, information) are not generally included. Moreover, the supply-side quality and degree of renewability of resources, in terms of biosphere activity leading to resource generation processes, are not generally taken into account in LCA evaluations. As a consequence, in

spite of the very valuable results that an LCA is capable to provide in terms of a process impacts, LCA leaves unaddressed aspects of resource quality in terms of the environmental work for resource generation as well as of environmental support to human-dominated and fully natural systems (value of natural capital and environmental services). This suggests a possible and much needed synergy with the EMergy Accounting approach.

EMergy Accounting (EMA) addresses the environmental work displayed by the past and present work of the Biosphere to generate resources and keep the entire system operating and evolving. In operational terms, emergy is defined as the available energy of one kind (usually solar) previously required, directly and indirectly, to make a service or product. The boundary of the analysis is always set at the biosphere level, thereby keeping track of the entire supply-chain (from resource generation to processing and disposal), and accounting for the environmental support needed to generate all the storages and flows of (renewable and non-renewable) raw natural resources which flow through the web of natural processes supporting the analysed process either directly or indirectly (e.g. in the form of ecosystem services). The unit of emergy is the solar emergy joule (sej), and the emergy to generate one unit of available energy or mass along a particular pathway is named transformity (sej/J) or, more generally, Unit Emergy Value (UEV, seJ/unit). The total emergy driving a system, calculated as the sum of all emergy inflows and also including the emergy investment for disposal or restoration, expresses the environmental cost of the product or service delivered (for further details see the abundant existing literature on the subject). After all the flows of interest have been quantified, a set of additional indicators: Environmental Loading Ratio (ELR), Emergy Yield Ratio (EYR), Emergy Sustainability Index (ESI), among others, can be developed for better understanding of a system's dynamics as well as for environmental policy making (sustainable resource use), by assessing the environmental performance of the process itself. The supply-side and biosphere-scale characteristics of the emergy approach make it capable to assess the demand for environmental support by every natural or human-dominated system or process, in so identifying its reliance on the overall biosphere functioning and interaction with other species and processes. The UEV plays the role of a potential eco-efficiency, in that it allows to compare similar products demanding more or less resources for their production and delivery.

The above-mentioned methods were jointly applied in order to provide, in sequence, (1) an identification of the major environmental and performance problems, (2) an understanding of the environmental cost of the proposed solutions, (3) an assessment of the performance of the system under study, as a consequence of the solution implementation.

The potentially available alternatives dealt with in the above point (2) can be grouped in the three following categories (all of which potentially rich of applicable options, and partially overlapping):

1) I-BAU: Improved Business as Usual – solutions that do not require new technologies, materials, sources (e.g., better use of existing techniques, waste prevention, "switch the light off when exiting the room" solutions);
2) TEI: Technology-based Efficiency Improvement – conservative estimates for solutions based on innovative technologies (e.g. LED instead of traditional lighting; heat pump instead of conventional heating systems; new materials, such as graphene and others - these may have a higher emergy cost, but be able to provide a comparatively larger benefit;
3) EEI: Eco-Efficiency Implementation – considering the substitution of resources characterized by higher environmental demand with selected alternatives with lower demand for environmental support (i.e. lower emergy cost, lower Unit Emergy Value: photovoltaic electricity instead of fossil powered electricity; use of recycled materials; use of resources with lower emergy intensity even if still non-renewable).

Tasks of deliverable 3.1 related to WP3

WP 3: Regional case studies of energy efficiency in Europe (from the proposed project, slightly modified according to later agreements with the Coordinator)

Description of work (where appropriate, broken down into tasks), lead partner and role of participants
Implementation of case studies will be carried out by means of a strict interaction with relevant stakeholders, in order to ensure appropriate understanding of the problem and appropriate design of solutions.

Task 3.1. Process level (Contribution by: Parthenope University, SERI…)
3.1a. Agriculture and livestock farms
3.1b. Wastewater treatment plants
3.1c. Waste-to-energy plants (e.g. gasification, anaerobic digestion, boilers, animal residues and waste cooking oil recovery for energy)
3.1d. Paper-making and paper-recycling industry

Task 3.2. Activity sector level (Contribution by: Parthenope University, SERI…)
3.2a. Urban waste management
3.2b. Urban transportation (individual car, mass transport, commodity distribution)
3.2c. Higher Education: Energy use in universities (merged with below task 3.3a)
3.2d. Electric and electronic waste management and recycling
3.2e. Food chain (with special attention to industrial food manufacture)

Task 3.3. System level (Contribution by: Parthenope University, Autonomous University of Barcelona)
3.3a. Energy use in buildings: a selection of different typologies of buildings (includes above task 3.2c).
3.3b. Urban energy metabolism: a selection of cities in the partner Countries.
3.3c. Main regional and national economies: a selection of regional and national systems in partner Countries.

Tasks of deliverable 3.2, 3.3 and 3.4 related to WP3

Task 3.4. Cost of solutions.
The efficiency of investigated case studies and their critical steps (efficiency drops) will be discussed with involvement of stakeholders and multicriteria experts, in order to understand solutions (if any) for higher energy efficiency. Solutions do not come for free. Environmental, material and energy costs and benefits, constraints and barriers to the implementation of solutions will be assessed (through LCA, emergy, MuSIASEM methods) with special attention to burden shift prevention. The energy cost for implementation of a given innovation may be higher that the energy benefits, or the environmental or social constraints may suggest to redesign or replace a given step or process.

Task 3.5. Large spatial and time scale cost and benefit assessment.
Identification of local or specific efficiency drops or improvements does not necessarily mean that the same consequences or solution apply Europewide. The extension of the analysis and of the solutions to the larger national scale or to the EU scale over time will be performed, through geographical exploration of needs, potentials and constraints (via GIS mapping). Design of scenarios of benefits over time, through the ASA models, will be performed.

Task 3.6. Standards for assessments.
Exploring the potential integration of the different approaches into a standard procedure for policy making. Testing the synergic effect of providing a multiplicity of indicators designed for different purpose. Pointing out the added value of results confirmed by more than one approach, but also of results that some methods are unable to identify, while other do. In so doing a comprehensive and bold basis for policy can be provided.

Deliverables

Deliverable 3.1: Report & Database. Results of LCA, Emergy, MuSIASEM methods applied to cases in Tasks 3.1, 3.2, 3.3. Delivery: Month 20. Responsible: Parthenope University.

Deliverable 3.2: Report on costs of solutions, initial findings and work in progress: Delivery: Month 29. Responsible: Parthenope University.

Deliverable 3.3: Report. Assessment of costs and benefits of energy efficiency solutions suggested and modelled in Tasks 3.4 and 3.4. Delivery: Month 40. Responsible: Parthenope University.

Deliverable 3.4: Report. Standardization and integration of assessment methods focused on energy efficiency. Delivery: Month 45. Responsible: Parthenope University

Acronyms and abbreviations

%REN = R/U: Fraction of emergy use that is renewable

BAU: Business As Usual

CC: Climate Change

CE: Circular Economy

CML: Center of Environmental Science of Leiden University

EC: European Commission

ELCD: European Life Cycle Database

EEI: Eco-Efficiency Implementation

ELR= (R+N+L+S)/R: Environmental Loading Ratio

EMA: Emergy Analysis

ESI= EYR/ELR: Emergy Sustainability Index

EYR= U/F= (R+N+F+L+S)/F: Emergy Yield Ratio

F: Emergy flows imported from outside (purchased) or supplied as feedback

FD: Fossil Depletion Potential

FU: Functional Unit

FE: Freshwater Eutrophication

HT: Human Toxicity Potential

HTML: HyperText Markup Language

ILCD: International Reference Life Cycle Data System Handbook

ISO: International Organization for Standardization

JRC: Joint Research Centre

L: Labor directly applied to the process (hours, converted to their emergy units). In this study, the term labor is also used in the decomposition equations to refer to all hours applied directly and indirectly (labor + services) to support the agricultural production.

L&S: Labor and Services

LCA: Life Cycle Assessment

LED: Light Emitting Diode

MD: Metal Depletion Potential

N: Locally nonrenewable or slow-renewable emergy flow

POF: Photochemical Oxidant Formation Potential

R: Locally renewable emergy flow

ReCiPe: methodology for Life Cycle Impact Assessment (LCIA)

S: Services: Indirect labor applied to the upstream processes that extract, refine and deliver goods to the investigated process. In general, services are quantified in terms of economic cost of indirect labor (€, $), converted to emergy units (seJ)

seJ: Solar emergy joule: unit used to quantify emergy flows

TA: Terrestrial Acidification Potential

TE: Terrestrial Eco-Toxicity

TEI: Technology-based Efficiency Improvement

U: Total emergy supporting the process or system under investigation. Sometimes referred to as "total emergy used".

UEV = U/output: Unit Emergy Value. Generic expression of emergy investment per unit of product of reference flow (seJ g-1; seJ €-1, etc). When the product is measured in energy units (J), the UEV is more frequently termed transformity (seJ J-1)

UPC: Urban Performance Calculator

WD: Water Depletion Potential

VBA: Visual Basic for Applications

List of tables

List of Figures

List of paper published in addition to the ones already included in deliverables 3.1, 3.2 and 3.3

List of papers submitted and still under review with Acknowledgement to EUFORIE project

Corcelli F., Fiorentino G., Petit-Boix A., Rieradevall J., Gabarrell X., 2018. Transforming rooftops into productive urban spaces in the Mediterranean. An LCA comparison of agri-urban production and photovoltaic energy generation. Submitted to Resources, Conservation and Recycling.

Santagata R., Viglia S., Fiorentino G., Liu G., Ripa M., 2018. Power generation from slaughterhouse waste materials. An Emergy Accounting assessment. Submitted to Journal of Cleaner Production.

Fiorentino G., Zucaro A., Ulgiati S., 2018. Towards an energy efficient chemistry. Switching from fossil to bio-based products in a life cycle perspective. Submitted to Energy.

Casazza M., Liu G., Mercuri E., Lega M., Ulgiati S., 2018. Under an eco-physics lens: a review of socio-ecological energy constraints and the future of civilization. Submitted to Energy Policy.

Vassillo C., Restaino D., Santagata R., Viglia S., Vehmas J., Ulgiati S., 2018. Energy efficiency and stakeholders: Barriers, costs and benefits of implementation. The Napoli (Italy) case study case study in the Euforie Project. Submitted to Journal of Environmental Accounting.

List of papers accepted with Acknowledgement to EUFORIE project

Rallo, R.F., and Zucaro, A., 2018. Assessing the energy metabolism of urban systems: A comparison of Napoli and Hong Kong via the MuSIASEM approach. Journal of Environmental Accounting and Management. Accepted for publication.

List of papers published with Acknowledgement to EUFORIE project

Xue, J.Y., Liu, G.Y., Casazza, M., Ulgiati, S., 2018. Development of an Urban FEW nexus online analyzer to support urban circular economy strategy planning. Energy 164, 475-495.

Corcelli, F., Fiorentino, G., Vehmas, J., Ulgiati, S., 2018. Energy efficiency and environmental assessment of papermaking from chemical pulp - A Finland case study. J. Clean. Prod. 198, 96–111. doi:10.1016/j.jclepro.2018.07.018

Huang S., An H., Viglia S., Fiorentino G., Corcelli F., Fang W., Ulgiati S., 2018. Terrestrial transport modalities in China concerning monetary, energy and environmental costs. Energy Policy, 122, 129-141.

Corcelli F., Ripa M., Leccisi E., Cigolotti V., Fiandra V., Graditi G., Sannino L., Tammaro M., Ulgiati S., 2018. Sustainable urban electricity supply chain – Indicators of material recovery and energy savings from crystalline silicon photovoltaic panels end-of-life. Ecol. Indic, 94, pp. 37-51. doi:10.1016/j.ecolind.2016.03.028.

Ghisellini P., Ripa M., Ulgiati S., 2018. Exploring environmental and economic costs and bene fits of a circular economy approach to the construction and demolition sector. A literature review. J. Clean. Prod. 178, 618–643. doi:10.1016/j.jclepro.2017.11.207

Corcelli F., Ripa M., Ulgiati S., 2018. Efficiency and sustainability indicators for papermaking from virgin pulp – An emergy-based case study. Resour. Conserv. Recycl. 131, 313–328. doi:10.1016/j.resconrec.2017.11.028Mehmeti, A., McPhail, S., Ulgiati, S., 2018. Fuel cell eco-efficiency calculator (FCEC): A simulation tool for the environmental and economic performance of high-temperature fuel cells. Energy 159, 1195-1205.

Fiorentino G., Ripa M. and Ulgiati S., 2017. Chemicals from biomass: technological versus environmental feasibility. A review. Biofuels, Bioproducts and Biorefining, 11: 195-214.

Ripa M. , Fiorentino G. , Vacca V. , Ulgiati S. , 2017. The relevance of site-specific data in Life Cycle Assessment (LCA). The case of the municipal solid waste management in the metropolitan city of Naples (Italy). Journal of Cleaner Production, 142(1): 445-460.

Corcelli F., Ripa M., Ulgiati S., 2017. End-of-life treatment of crystalline silicon photovoltaic panels. An emergy-based case study. J. Clean. Prod., 161, pp. 1129-1142 doi.org/10.1016/j.jclepro.2017.05.031.

Santagata, R., Ripa, M., Ulgiati, S., 2017. An environmental assessment of electricity production from slaughterhouse residues. Linking urban, industrial and waste management systems. Appl. Energy 186, 175–188. https://doi.org/10.1016/j.apenergy.2016.07.073

Viglia, S., Civitillo, D.F., Cacciapuoti, G., Ulgiati, S., 2017. Indicators of environmental loading and sustainability of urban systems. An emergy-based environmental footprint. Ecol. Indic. 94(3): 82-99. https://doi.org/10.1016/J.ECOLIND.2017.03.060

List of papers/Extended Abstract in a Conference Book of Proceedings with Acknowledgement to EUFORIE project:

Corcelli F., Fiorentino G., Vehmas J., Ulgiati S. “Energy efficiency and environmental sustainability indicators for papermaking from chemical pulp. A Finland case study”. 10th Biennial International Workshop “Advances in Energy Study”, 25-28 September 2017, Napoli (Italy). ISBN 978-3-85125-513-3

Huang S., An H., Wen S., Fang W., Fiorentino G., Corcelli F., Ulgiati S. “Revisiting terrestrial transport modalities in China: a survey of monetary, energy and environmental costs”. 10th Biennial International Workshop “Advances in Energy Study”, 25-28 September 2017, Napoli (Italy). ISBN 978-3-85125-513-3.

Corcelli F., Ripa M., Leccisi E., Cigolotti V., Fiandra V., Tammaro M., Sannino L., Graditi G., Ulgiati S., 2015. Material recovery and energy savings from c-Si PV panels end-of-life. Life Cycle Assessment of PV panels thermal treatment. In Proceedings of the Global Cleaner Production and Sustainable consumption Conference, Sitges (Spain) 1–4 November 2015.

Sánchez L.P., Ripa M., Velasco-Fernández R., Gamboa G., Rallo R.F., Giampietro M., 2017. Energy performance at city level − the societal metabolism of Barcelona. 10th Biennial International Workshop “Advances in Energy Study”, 25-28 September 2017, Napoli (Italy). ISBN 978-3-85125-513-3.

Introduction

The aim of deliverable D3.4 is to design a user-friendly prototype tool aimed to support stakeholders and policy makers when dealing with discussion and decision processes about environmental sustainability issues. The EUFORIE Prototype Tool is not intended to be a commercial software (out of the scope of WP3), but it is a to-be-improved information technology resource that should be considered as the starting point for a fully developed sustainability toolkit (perhaps the objective for a future project).

The EUFORIE Prototype Tool is not intended as a ready-to-use online tool, since the transfer of rationale and theoretical schematization to even a beta version of a usable tool requires much more resource investment and information technology expertise than available in the EUFORIE project Consortium and budget. However, the tool will design a roadmap to achieve such a result, if this is believed important at EU level.

In this deliverable a step by step procedure (Chapter 1) and a specific application (Chapter 2) of the EUFORIE Prototype Tool are presented. The case study of the City of Napoli was selected from deliverables D3.1 and D3.3 as representative of the system level to which lower levels of processes and sectors converge. The Napoli-based Urban Performance Calculator (UPC) represents the first attempt of the application of the EUFORIE Prototype Tool to the selected case study (the system level – City of Napoli), to show how the tool works and the main results achieved by its application.

The procedure starts with a preliminary Life Cycle Assessment analysis (ex-ante LCA), allowing the identification of the input flows that are the main responsible of the largest impacts from the process. Once the most impacting inputs are identified, different solution scenarios are designed (Business-as-Usual, Technological Efficiency, Eco-Efficiency) and evaluated by means of the Emergy Analysis approach, in order to compare the proposed solutions based on their environmental cost. The scenario assessment and comparison is supported by a simulation program designed to help quantitative understanding of how and to what extent the assumed amount and quality variations of input flows affect the final performance indicators. Finally, an ex-post LCA is foreseen, in order to confirm if the suggested solutions have been able to solve the identified impact problems:

ex-ante LCA ==> identification of performance problems ==> simulation of BaU, Technological and eco-Efficiency Solution Scenarios ==> ex-post LCA ==> assessment of achieved solution.

As described in more details in previous deliverables, the two approaches used within the EUFORIE Prototype Tool can be described as follows:

Life Cycle Assessment (LCA) stems from the basic principle that in order to accurately assess the environmental impact of a system or product, all its productive stages must be included in the analysis, "from cradle to grave', i.e. from resource extraction to final disposal. Several impacts are evaluated and indicators developed in order to provide a clear picture of resource use and environmental damage generated within a process or an economy. The recently published International Life Cycle Data System (ILCD) Handbook (ILCD, 2010), made available through the European Platform on LCA, further confirms the importance of LCA as a decision-supporting tool in contexts ranging from product development to policy making. The Handbook, a series of technical guidance documents to the ISO 14040-44 standards (ISO, 2006a; ISO, 2006b), serves as a basis for comparable and reliable LCA applications in business and public decision-making. Methodologically, a LCA is structured in four consecutive stages, namely: (i) goal and scope definition (including a clear definition of the functional unit, system boundaries and associated assumptions); (ii) life cycle inventory (the compilation of all the inputs and outputs respectively from and to nature associated to all processes that form part of the system's life cycle); (iii) life cycle impact assessment (in which the full inventory of inputs and outputs is translated into a number of aggregated metrics of environmental impact); and (iv) interpretation (in which results are discussed and compared to suitable benchmarks). In all cases, LCA only accounts for matter and energy flows occurring under human control, whereas flows outside of market dynamics (such as environmental services and renewable resources that do not flows through human controlled devices) as well as flows which are not associated to significant matter and energy carriers (such as labor, culture, information) are not generally included. Moreover, the supply-side quality and degree of renewability of resources, in terms of biosphere activity leading to resource generation processes, are not generally taken into account in LCA evaluations. As a consequence, in spite of the very valuable results that an LCA is capable to provide in terms of a process impacts, LCA leaves unaddressed aspects of resource quality in terms of the environmental work for resource generation as well as of environmental support to human-dominated and fully natural systems (value of natural capital and environmental services). This suggests a possible and much needed synergy with the EMergy Accounting approach.

EMergy Accounting (EMA) addresses the environmental work displayed by the past and present work of the Biosphere to generate resources and keep the entire system operating and evolving. In operational terms, emergy is defined as the available energy of one kind (usually solar) previously required, directly and indirectly, to make a service or product (Odum 1996, Brown & Ulgiati 2016). The boundary of the analysis is always set at the biosphere level, thereby keeping track of the entire supply-chain (from resource generation to processing and disposal), and accounting for the environmental support needed to generate all the storages and flows of (renewable and non-renewable) raw natural resources which flow through the web of natural processes supporting the analysed process either directly or indirectly (e.g. in the form of ecosystem services). The unit of emergy is the solar emergy joule (sej), and the emergy to generate one unit of available energy or mass along a particular pathway is named transformity (sej/J) or, more generally, Unit Emergy Value (UEV, seJ/unit). The total emergy driving a system, calculated as the sum of all emergy inflows and also including the emergy investment for disposal or restoration, expresses the environmental cost of the product or service delivered (for further details see the abundant existing literature on the subject). After all the flows of interest have been quantified, a set of additional indicators: Environmental Loading Ratio (ELR), Emergy Yield Ratio (EYR), Emergy Sustainability Index (ESI), among others, can be developed for better understanding of a system's dynamics as well as for environmental policy making (sustainable resource use), by assessing the environmental performance of the process itself. The supply-side and biosphere-scale characteristics of the emergy approach make it capable to assess the demand for environmental support by every natural or human-dominated system or process, in so identifying its reliance on the overall biosphere functioning and interaction with other species and processes. The UEV plays the role of a potential eco-efficiency, in that it allows to compare similar products demanding more or less resources for their production and delivery.

The above-mentioned methods were jointly applied in order to provide, in sequence, (1) an identification of the major environmental and performance problems, (2) an understanding of the environmental cost of the proposed solutions, (3) an assessment of the performance of the system under study, as a consequence of the solution implementation. The development of the different scenarios was carried out introducing a random variation, within a chosen range, of the magnitude of the identified hotspots, as below indicated.

The potentially available alternatives dealt with in the above point (2) can be grouped in the three following categories (all of which potentially rich of applicable options, and partially overlapping):

1. **Improved Business As Usual (I-BAU)**, evaluating the system as it is, with focus on the sensitivity of results to uncertainty of input and output data as well as to the willingness to apply a wise and rational use of resources (e.g., better use of existing techniques, waste prevention, "switch the light off when exiting the room" solutions) , in order to better understand the system's behavior and impacts before any decision is made). The random variation considered in this scenario is between -10% and +10%, in order to show the sensitivity of results, but different ranges may be selected for each resource input depending on the specific strategy;

2. **Technology-based Efficiency Improvement (TEI**), to suggest improvements of the investigated level through energy and material technological efficiency, according to the LCA approach (e.g., by considering a reduction of the main energy and material input flows through technological innovation, such as design, cohibentation, light emission diode-LED technology, heat pumps instead of conventional heating systems, new materials such as graphene and others - these may have a higher emergy cost, but be able to provide a comparatively larger benefit). The random variation considered in this scenario is between -20% and 0%, i.e. assumed and planned decrease of resource demand.

3. **Eco-Efficiency Implementation (EEI)**, i.e. achievable improvements of the environmental sustainability by substituting energy and material hotspots with renewable or less environmental costly input flows according to the EMA approach (less specific emergy UEV, such as photovoltaic electricity instead of fossil powered electricity; use of recycled materials; use of resources with lower emergy intensity even if still non-renewable). Technology-based Efficiency Improvement and Eco-efficiency can be applied separately to each investigated case and level, or even together to detect the potential for further improvement. The random variation considered in this scenario is between -10% and -5%.

A general assumption is made about the output generated: we assume that the same product is obtained thanks to oscillating (I-BAU), decreasing (TEI), and quality increasing (EEI) input flows. In order to compare on the same basis the results of the three scenarios, the emergy performance indicators (total U and UEVs) are compared. Of course, a likewise comparison would be impossible if - for example - the I-BAU scenarios were assessed in energy terms, the TEI in LCA terms and the EEI in EMA terms, i.e. non comparable metrics. In each investigated scenario, a decrease of the environmental burdens is expected, but not granted, and can be assessed by an ex-post LCA evaluation.

The flow chart in Figure 1 represents the EUFORIE Prototype Tool framework, highlighting the connections between the components, i.e. the methods used (LCA and EMA) and the built scenarios, which could be considered once at a time as well as all together. The feedback from the Ex-Post LCA indicates potential scenario re-adjustments made necessary after Ex-Post results.

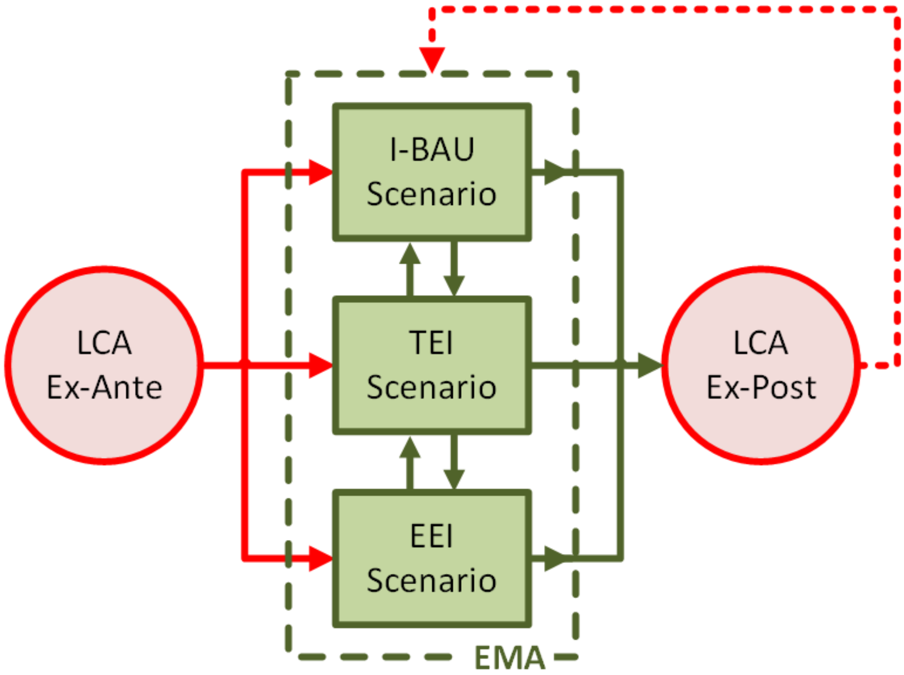


Figure 1 – EUFORIE Prototype Tool Framework.

In Figure 2 the interconnections happening within a circular economy framework applied to a urban system are highlighted: the so called "waste" exiting each compartment (Agriculture, Industrial process, Urban sub-system) is partially re-used as secondary source and re-circulated within the whole system.
The development of the prototype tool is aimed at merging the knowledge of LCA and EMA frameworks for synergic results. The LCA represents a standardized method providing qualitative, quantitative, confirmable and manageable environmental performance of the investigated processes or products, as defined by ISO standards and ILCD Handbook guidelines (ISO, 2006a; ISO, 2006b; EC, 2010; EC, 2011). EMA integrates renewable sources, resource generation time, trade flows, resource quality aspects, labor and services in the LCA approach (Figure 3). Further details on the used methodologies are reported in deliverable D3.1.

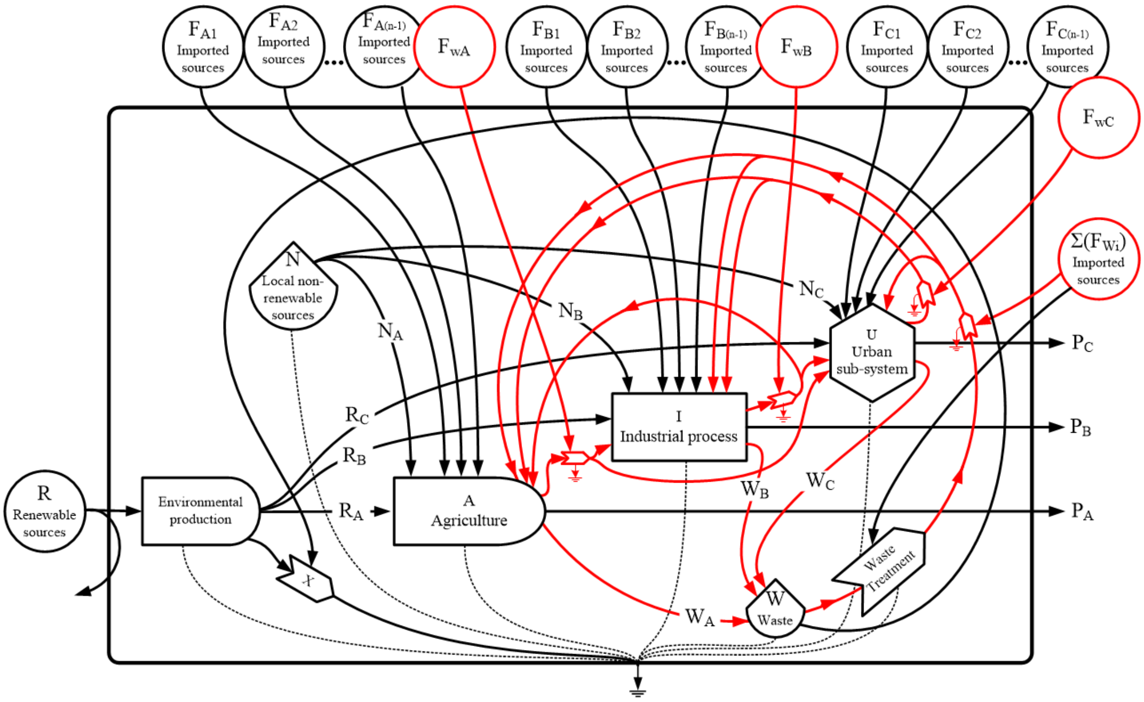
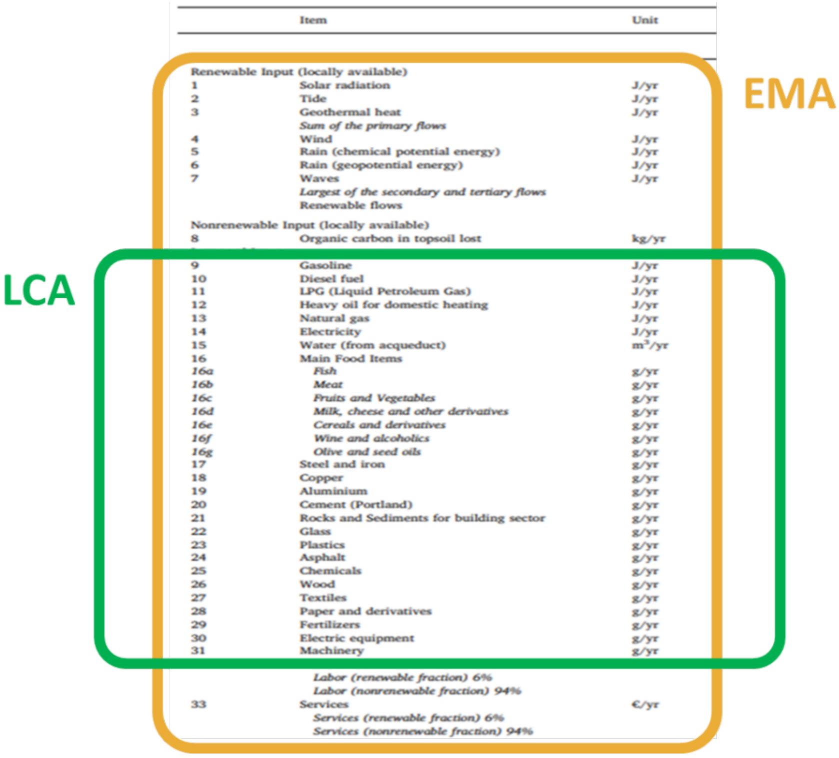


Figure 2 – System diagram of the integrated circular system. It shows the interconnections between the different levels presented in a circular framework.



	Item	Unit
Renewable Input (locally available)		
1	Solar radiation	J/yr
2	Tide	J/yr
3	Geothermal heat	J/yr
	Sum of the primary flows	
4	Wind	J/yr
5	Rain (chemical potential energy)	J/yr
6	Rain (geopotential energy)	J/yr
7	Waves	J/yr
	Largest of the secondary and tertiary flows	
	Renewable flows	
Nonrenewable Input (locally available)		
8	Organic carbon in topsoil lost	kg/yr
9	Gasoline	J/yr
10	Diesel fuel	J/yr
11	LPG (Liquid Petroleum Gas)	J/yr
12	Heavy oil for domestic heating	J/yr
13	Natural gas	J/yr
14	Electricity	J/yr
15	Water (from acqueduct)	m³/yr
16	Main Food Items	
16a	*Fish*	g/yr
16b	*Meat*	g/yr
16c	*Fruits and Vegetables*	g/yr
16d	*Milk, cheese and other derivatives*	g/yr
16e	*Cereals and derivatives*	g/yr
16f	*Wine and alcoholics*	g/yr
16g	*Olive and seed oils*	g/yr
17	Steel and iron	g/yr
18	Copper	g/yr
19	Aluminium	g/yr
20	Cement (Portland)	g/yr
21	Rocks and Sediments for building sector	g/yr
22	Glass	g/yr
23	Plastics	g/yr
24	Asphalt	g/yr
25	Chemicals	g/yr
26	Wood	g/yr
27	Textiles	g/yr
28	Paper and derivatives	g/yr
29	Fertilizers	g/yr
30	Electric equipment	g/yr
31	Machinery	g/yr
	Labor (renewable fraction) 6%	
	Labor (nonrenewable fraction) 94%	
33	Services	€/yr
	Services (renewable fraction) 6%	
	Services (nonrenewable fraction) 94%	

Figure 3 – The interaction between LCA and EMA methods.

The EUFORIE Prototype Tool is developed for participatory processes at different levels starting from previous attempts carried out within the EUFORIE research team at Parthenope for the performance evaluation of energy systems (Bargigli et al., 2010; Zucaro et al., 2013; Mehmeti et al., 2018) and urban systems (Casazza et al., 2017; Xue et al., 2018), and also as a follow up of previous national and EU research projects, by taking advantage of the large network of collaboration links of Parthenope with other research groups worldwide.

The EUFORIE Prototype Tool is composed with:
i) an ex-ante LCA analysis to identify the main hotspots;
ii) an Excel spreadsheet used in order to analyze the environmental loading of the systems under investigation, as follows:
- the user's interface, where the inventory of input and output flows is listed;
- calculation procedure sheet, where calculation procedures applied, accessible only to the operator, are reported;
- emergy intensities (UEV) sheet, where updated UEV values are listed;
- emergy sheet, in which emergy flows and the total emergy U of the system are evaluated;
- emergy variation sheet, in which the scenarios, through a Visual Basic Applications (VBA) macro, are built through magnitude variation of selected hotspots and the random variation of total emergy U is calculated
- summary sheet, where variation charts are reported;

iii) an interactive graphical layout, to display different sets of results based on a HTML (Hyper Text Markup Language)/Java application capable of highlighting different charts related to the several variations of each investigated scenario;
iv) an ex-post LCA analysis in order to evaluate and verify the environmental performance (e.g. lower impact generated) of each investigated scenario and suggest the better scenario achieved.

References

Bargigli, S., Cigolotti, V., Pierini, D., Moreno, A., Iacobone, F., and Ulgiati, S., 2010. Cogeneration of heat and electricity. A comparison of gas turbine, internal combustion engine and MCFC/GT hybrid system alternatives. Journal of Fuel Cell Science and Technology, 7: 011019.1-011019.6.

Brown, M.T., Ulgiati, S., 2016. Emergy assessment of global renewable sources. Ecol. Modell. 339, 148–156. https://doi.org/10.1016/j.ecolmodel.2016.03.010

Casazza, M., Liu, G.Y., Xue, J.Y., Meng, F.X., Gao, Y., Liu, X.Y., Yang, Z.F., Ulgiati, S., 2017. Food-Energy-Water Nexus Analysis in Urban Circular Economy Strategy. In: Energy Futures, Environment and Wellbeing (Sergio Ulgiati and Laura Vanoli Eds), Book of Proceedings of the 10th BIWAES-Biennial International Workshop Advances in Energy Studies, Verlag der Technischen Universitat Graz, Pp. 431-438. ISBN 978-3-85125-513-3.

European Commission (EC) – Joint Research Center – Institute of Environment and Sustainability, 2010. International Reference Life Cycle Data System (ILCD) Handbook – General Guide for Life Cycle Assessment – Detailed Guidance. EUR 24708 EN. Publications Office of the European Union, Luxembourg, LU.

European Commission (EC) – Joint Research Center – Institute of Environment and Sustainability, 2011. Supporting Environmentally Sound Decisions for Waste Management – A technical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA) for waste experts and LCA practitioners. EUR 24916 EN. Publications Office of the European Union, Luxembourg, LU.

ISO 14040, International Standard, 2006a. Environmental Management – Life Cycle Assessment – Principles and Framework. International Organization for Standardization, Geneva, Switzerland.

ISO 14044, International Standard, 2006b. Environmental Management – Life Cycle Assessment – Requirements and Guidelines. International Organization for Standardization, Geneva, Switzerland.

Mehmeti, A., McPhail, S., Ulgiati, S., 2018. Fuel cell eco-efficiency calculator (FCEC): A simulation tool for the environmental and economic performance of high-temperature fuel cells. Energy. Accepted for publication.

Odum, H.T., 1996. Environmental Accounting: Emergy and Environmental Decision Making. New York.

Xue, J.Y., Liu, G.Y., Casazza, M., Ulgiati, S., 2018. Development of an Urban FEW nexus online analyzer to support urban circular economy strategy planning. Submitted to Energy. Under review.

Zucaro, A., Fiorentino, G., Zamagni, A., Bargigli, S., Masoni, P., Moreno, A., Ulgiati, S., 2013. How can life cycle assessment foster environmentally sound fuel cell production and use? International Journal of Hydrogen Energy 38, 453-468.

Chapter 1 – Step by step EUFORIE Prototype Tool development

The evaluation of the environmental performance of selected system has to be carried out by means of the LCA/EMA EUFORIE Prototype Tool. As mentioned earlier in this Deliverable, this tool allows to: i) evaluate the process environmental sustainability; ii) measure the process environmental profitability through several LCA/emergy-based indicators and their variation; iii) provide information and support to policy makers and other stakeholders involved in decision making.
As a first step, a LCA/EMA expert creates an interactive inventory, defined by the investigated system (each system has a particular data inventory), in which all relevant input and output flows (specifying for each one the adequate unit measure) are listed. Afterwards, the user is only capable of inserting the proper amount for each input and output flow specified in the inventory (Figure 4).

1	2	3	4
Note	Item	Raw amount	Units
1.	First item	xx.x	g or J/yr
2.	Second item	xx.x	g or J/yr
..			
..			
n.	n^{th} item	xx.x	g or J/yr
O.	Output(s)	xx.xx	g or J/yr

Figure 4 – LCA/EMA inventory data sheet example.

The identified inventory is used to perform the LCA analysis. The LCA impact assessment is performed by means of a specific LCA analysis software (i.e. SimaPro, GaBi, OpenLCA) coupled with a proper database (i.e. EcoInvent, ELCD, Agri-footprint) and impact assessment method (ReCiPe, CML, ILCD). The LCA procedure provides the opportunity to identify the main hotspots for each investigated impact category and for the whole investigated system.

Table 1 shows an example of relevant LCA impact categories.

Table 1 – Example of LCA impact categories (ReCiPe Midpoint (H)).

Impact category	Abbreviation	Unit
Climate change	CC	kg CO_2 eq
Ozone depletion	OD	kg CFC-11 eq
Terrestrial acidification	TA	kg SO_2 eq
Freshwater eutrophication	FE	kg P eq
Marine eutrophication	ME	kg N eq
Photochemical oxidant formation	POF	kg NMVOC eq
Particulate matter formation	PMF	kg PM_{10} eq
Water depletion	WD	m^3
Fossil depletion	FD	kg oil eq

Once identified the hotspots, the EMA procedure is applied. All input flows are listed in a spreadsheet inventory (User Interface), and properly converted accordingly with the EMA procedure to the right unit measure (Calculation spreadsheet) and then multiplied by the proper UEV, listed in Emergy intensities spreadsheet, in order to evaluate a set of indicators (i.e. total emergy U, UEV of output flows). Figure 5 shows a typical EMA table, in which:

- Column #1 is the line item number, which is also the number of input in the user interface (inventory data sheet).
- Column # 2 is the name of the item.
- Column # 3 is the raw data in the proper unit measure (joules, grams, hours, € or other units).
- Column 4 shows the fixed unit measures for each raw data.
- Column # 5 is the Intensity factor (UEV).
- Column # 6 is the total emergy value for each flow and for the total investigated system, calculated by multiplying the i-th raw input (item) by its relative UEV (Column 3 by Column 5).

1	2	3	4	5	6
Note	Item	Raw amount	Units	Intensity Factor (sej/unit)	Total Amount (sej/yr)
1.	First item	xx.x	g or J/yr	xxx.x	xxx.x
2.	Second item	xx.x	g or J/yr	xxx.x	xxx.x
..					
..					
n.	n^{th} item	xx.x	g or J/yr	xxx.x	xxx.x
O.	Output(s)	xx.xx	g or J/yr	xxx.x	$\sum_{n}^{1} Ej$

Figure 5 – EMA table.

For each hotspot is then applied a Visual Basic for Applications (VBA) excel based macro, to perform a random variation within a selected range, fixed for each different scenario (I-BAU, TEI and EEI). The

VBA macro (Table 2) will compute 200 random values, updating the various indicators and plotting them into graphs, within an Emergy variation spreadsheet in which all the Emergy indicators where properly calculated and summarized. The last sheet of the EMA excel platform is a summary table reporting the main input flows and the obtained EMA indicators.

Table 2 – VBA code for the creation of 200 random values within a range. The same code is applied to the different input flows (once chosen x, y, z, j and k value accordingly).

Range(Cells(x, y), Cells(65536, y)).ClearContents	***To clear the cells where results will be shown.***
a = Cells(z, y).Value	***Variable a equal to value of input flow, from cell (z,y)***
b = Cells(z, j).Value	***Variable b equal to minimum of variation range, from cell (z,j)***
c = Cells(z, k).Value	***Variable c equal to maximum of variation range, from cell (z,k)***
r = 0	***Random value variable***
t = 0	***Loop counting variable***
i = x	***Start printing results from row x***
Randomize	***Beginning of randomization function***
Do Until t > 200	***To obtain 200 different values***
r = WorksheetFunction.RandBetween(b, c)	***r is equal to a random value between the minimum and the maximum of the range***
r = r / 100	***Random value to percentage***
Cells(i, j) = r	***Random value printed in cell (i, j)***
Cells(i, y) = a + (a * r)	***Value of input flow times the random percentage and printed***
t = t + 1	***Counter increase by 1***
i = i + 1	***Move to next row***
Loop	***Loop for 200 times***

The obtained results are plotted and displayed by the last component of the tool, which is a HTML (HyperText Markup Language)/Java based application capable of highlighting different charts related to the several variations of each investigated scenario, built upon the Highcharts charting library (www.highcharts.com). Figure 6 shows an example of the described procedure applied to a generic system, for the I-BAU scenario. The charts display the variation of total emergy U with and without Labor and Services (L&S) resulting by the variation of three different hotspots considered once at the time and all together at the same time, as explained by the four buttons on the bottom of the chart. The fully working tool can be accessed within the EUFORIE website (www.euforie-h2020.eu).

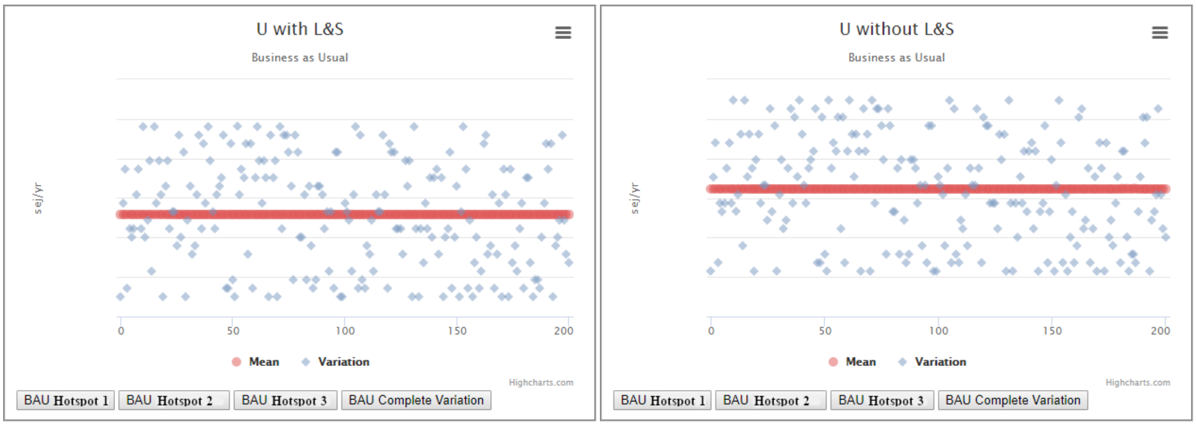


Figure 6 – EUFORIE Prototype Tool charts (U with and without L&S, I-BAU scenario).

Table 3 illustrates the HTML code related to the EUFORIE Prototype Tool, while Table 4 shows the code of the Java script needed for the tool. Other Java scripts are related to the general functioning of Java and Highcharts and therefore they are not included in this deliverable.

Table 3 – HTML code for the EUFORIE Prototype Tool.

<html lang="en" > <head> <meta charset="UTF-8"> <title>EUFORIE Prototype Tool</title> </head> <body>	***Start of the html page with title***
style type="text/css"> #BAUwith {float:left;} #BAUwithout {float:left;} #EEIwith {float:left;} #EEIwithout {float:left;} #TEIwith {float:left;} #TEIwithout {float:left;} </style>	***Code to define the position of the graphs within the page***

<script src='http://cdnjs.cloudflare.com/ajax/libs/jquery/2.1.3/jquery.min.js'></script> <script src='https://code.highcharts.com/highcharts.js'></script> <script src= 'http://code.highcharts.com/modules/exporting.js' ></script> <!—optional Module –> <script src= 'http://code.highcharts.com/modules/offline-exporting.js'></script>	***Code to call Java and Highcharts scripts needed for the Urban Performance Calculator functioning***
EUFORIE Prototype Tool ---INSERT NAME OF CASE STUDY--- The EUFORIE Prototype Tool is based on the integration of LCA (Life Cycle Assessment) and EMA (EMergy Accounting) methods suggested as a useful support to the stakeholders and policy makers discussion and decision processes The hot-spot inputs identified by means of LCA method within the selected case study are: 1) ---INSERT HOTSPOT---; 2) ---INSERT HOTSPOT---; 3) ---INSERT HOTSPOT---. Total Emergy (U) values for i) Business As Usual, ii) EcoEfficiency Implementation, iii) Technology-based Efficiency Improvement scenarios are shown, with and without Labor and Services (L&S) 	***Generic text section explaining the tool (insert desired information).***

```
<h2>Business as Usual</h2>
<p>Variation between -10% and +10% of selected hot-spots</p>
<fieldset id="BAUwith">
<div id="containerA" style="width: 600px; height: 400px;"></div>
<button id="button">BAU ---INSERT HOTSPOT---</button>
<button id="button2">BAU ---INSERT HOTSPOT---</button>
<button id="button3">BAU ---INSERT HOTSPOT---</button>
<button id="button4">BAU Complete Variation</button>
<script  src="script1.js"></script>
</fieldset>
<fieldset id="BAUwithout">
<div id="containerB" style="width: 600px; height: 400px;"></div>
<button id="button5">BAU ---INSERT HOTSPOT---</button>
<button id="button6">BAU ---INSERT HOTSPOT---</button>
<button id="button7">BAU ---INSERT HOTSPOT---</button>
<button id="button8">BAU Complete Variation</button>
<script  src="script2.js"></script>
</fieldset>
<br style="clear:both" />
<ul>
<li><strong>BAU ---INSERT HOTSPOT---</strong>: Variation of U resulting from variation of ---INSERT HOTSPOT--- input</li>
<li><strong>BAU ---INSERT HOTSPOT---</strong>: Variation of U resulting from variation of ---INSERT HOTSPOT---input</li>
<li><strong>BAU ---INSERT HOTSPOT---</strong>: Variation of U resulting from variation of ---INSERT HOTSPOT--- input</li>
<li><strong>BAU Complete Variation</strong>: Variation of U resulting from variation of all hot-spots</li>
</ul>

<br style="clear:both" />
<br>
<br>
```

Section of code relative to the BAU scenario. The first lines of code of the “with L&S” and of the “wthout L&S” fieldsets are to define the containers (i.e. the dedicated spaces) for the charts and the buttons needed to switch between the different assumptions . The last line before closing the fieldsets is to call the script that builds the chart. Other lines are generic text for description.

```
<h2>Technology-based Efficiency Improvement</h2>
<p>Variation between -20% and 0% of selected hot-spots, resulting from a more efficient use of resources</p>
<fieldset id="TEIwith" >
<div id="containerE" style="width: 600px; height: 400px;"></div>
<button id="button17">TEI ---INSERT HOTSPOT---</button>
<button id="button18">TEI ---INSERT HOTSPOT---</button>
<button id="button19">TEI ---INSERT HOTSPOT---</button>
<button id="button20">TEI Complete Variation</button>
<script  src="script5.js"></script>
</fieldset>
<fieldset id="TEIwithout" >
<div id="containerF" style="width: 600px; height: 400px;"></div>
<button id="button21">TEI ---INSERT HOTSPOT---</button>
<button id="button22">TEI ---INSERT HOTSPOT---</button>
<button id="button23">TEI ---INSERT HOTSPOT---</button>
<button id="button24">TEI Complete Variation</button>
<script  src="script6.js"></script>
</fieldset>
<br style="clear:both" />
<ul>
<li><strong>TEI ---INSERT HOTSPOT---</strong>: Variation of U resulting from variation of ---INSERT HOTSPOT--- input</li>
<li><strong>TEI ---INSERT HOTSPOT---</strong>: Variation of U resulting from variation of ---INSERT HOTSPOT--- input</li>
<li><strong>TEI ---INSERT HOTSPOT---</strong>: Variation of U resulting from variation of ---INSERT HOTSPOT--- input</li>
<li><strong>TEI Complete Variation</strong>: Variation of U resulting from variation of all hot-spots</li>
</ul>

<br style="clear:both" />
<br>
<br>
```

Section of code relative to the TEI scenario. The first lines of code of the “with L&S” and of the “wthout L&S” fieldsets are to define the containers (i.e. the dedicated spaces) for the charts and the buttons needed to switch between the different assumptions. The last line before closing the fieldsets is to call the script that builds the chart. Other lines are generic text for description.

<h2>EcoEfficiency Implementation</h2> <p>Variation between -10% and -5% of selected hot-spots</p> <fieldset id="EEIwith" > <div id="containerC" style="width: 600px; height: 400px;"></div> <button id="button9">EEI ---INSERT HOTSPOT---</button> <button id="button10">EEI ---INSERT HOTSPOT---</button> <button id="button11">EEI ---INSERT HOTSPOT---</button> <button id="button12">EEI Complete Variation</button> <script src="script3.js"></script> </fieldset> <fieldset id="EEIwithout" > <div id="containerD" style="width: 600px; height: 400px;"></div> <button id="button13">EEI ---INSERT HOTSPOT---</button> <button id="button14">EEI ---INSERT HOTSPOT---</button> <button id="button15">EEI ---INSERT HOTSPOT---</button> <button id="button16">EEI Complete Variation</button> <script src="script4.js"></script> </fieldset> <br style="clear:both" /> EEI ---INSERT HOTSPOT---: Variation of U resulting from variation of ---INSERT HOTSPOT--- input EEI ---INSERT HOTSPOT---: Variation of U resulting from variation of ---INSERT HOTSPOT--- input EEI ---INSERT HOTSPOT---: Variation of U resulting from variation of ---INSERT HOTSPOT--- input EEI Complete Variation: Variation of U resulting from variation of all hot-spots <br style="clear:both" /> 	***Section of code relative to the TEI scenario. The first lines of code of the “with L&S” and of the “wthout L&S” fieldsets are to define the containers (i.e. the dedicated spaces) for the charts and the buttons needed to switch between the different assumptions. The last line before closing the fieldsets is to call the script that builds the chart. Other lines are generic text for description.***
</body> </html>	***End of code.***

Table 4 – Code for the charts javascript.

```
$(function () {
var chart = new Highcharts.Chart({
chart: {
type: 'scatter',
renderTo: 'container',
zoomType: 'xy'
},
title: {
text: 'U with L&S'
},
subtitle: {
text: 'Business as Usual'
},
yAxis: {
title: {
text: 'sej/yr'
}
},
legend: {
align: 'center',
verticalAlign: 'bottom',
x: 0,
y: 0,
floating: false,
backgroundColor: (Highcharts.theme &&
Highcharts.theme.legendBackgroundColor) ||
'#FFFFFF',
borderWidth: 0
},
plotOptions: {
scatter: {
marker: {
radius: 5,
states: {
hover: {
enabled: true,
lineColor: 'rgb(100,100,100)'
}
}
},
states: {
hover: {
marker: {
enabled: false
}
```

Start of the code, defining the type of charts and the generic appearance of the graphs. This section also define the title and subtitle of the charts, labels of the axis and the default series of data to show.

```
            }
        },
        tooltip: {
            headerFormat:
            '<b>{series.name}</b><br>',
            pointFormat: '{point.x}, {point.y}'
            }
        }
    },
    series: [{
        name: 'Serie 1',
        color: 'rgba(223, 83, 83, .5)',
        data: [x_1, x_2, x_3, …, x_n]
    }, {
        name: 'Serie 2',
        color: 'rgba(119, 152, 191, .5)',
        data: [x'_1, x'_2, x'_3, …, x'_n]
    }]
});

// The button action
$('#button').click(function() {
    chart.series[0].setData([x_1, x_2, x_3, …, x_n] )
    chart.series[1].setData([x'_1, x'_2, x'_3, …, x'_n]
    );
});
$('#button2').click(function() {
    chart.series[0].setData([y_1, y_2, y_3, …, y_n] )
    chart.series[1].setData([y'_1, y'_2, y'_3, …, y'_n]
    );
});
$('#button3').click(function() {
    chart.series[0].setData([z_1, z_2, z_3, …, z_n] )
    chart.series[1].setData([z'_1, z'_2, z'_3, …, z'_n]
    );
});
$('#button4').click(function() {
    chart.series[0].setData([w_1, w_2, w_3, …,
    w_n] )
    chart.series[1].setData([w'_1, w'_2, w'_3, …,
    w'_n] );
});
});
```

This section defines the behavior of the buttons and the sets of data to show. The set of data relative to the first button is the same as the default set of data.

References

European Futures for Energy Efficiency (EUFORIE) – Project website: https://www.euforie-h2020.eu/

Highcharts: Interactive JavaScript charts for your webpage – Available at https://www.highcharts.com/

Java: James Gosling, Bill Joy, Guy Steele, Gilad Bracha, Alex Buckley, The Java Language Specification, Java SE 8 Edition

Chapter 2 – EUFORIE Prototype Tool: The Urban Performance Calculator as case study

An application of the EUFORIE Prototype Tool, called Urban Performance Calculator (UPC), is presented in this chapter. The system level represents the most complex and interconnected stage to describe and clarify how the tool works.
The UPC has been developed upon the results achieved in EUFORIE D3.3, therefore the selected urban system is the City of Napoli, located in Campania region, southern Italy (detailed description of the investigated system reported in Viglia et al., 2017, work carried out in the framework of EUFORIE project). The UPC aims at evaluating the environmental performance at **system level.** In particular, this tool allows to: i) evaluate the urban environmental sustainability; ii) measure the urban system metabolism through several LCA/emergy-based indicators and their variation; iii) provide information and support to policy makers and other stakeholders involved in decision making.

The working procedure is the same as described in Chapter 1 and available in the EUFORIE project website for testing. The first step is the construction of the inventory, where the interested stakeholder can quantify the input and output flows (Figure 7).

Urban Performance Calculator

Year		2011
Urban area	m^2	1.17E+08
Continental Shelf area	m^2	9.00E+08
Coast Lenght	m	5.47E+04

#	Item	Unit	Value	Variation	Sensitivity Adjusted Value
1	**Sun insolation**	$J/m^2/yr$	5.49E+09	5%	5.76E+09
2	**Geothermal heat**				
	Average heat flow from urban area	mW/m^2	10.00	0%	1.00E+01
	Average heat flow from continental Shelf area	mW/m^2	86.00	0%	8.60E+01
3	**Tidal energy (avg. tide range)**	m	0.30	0%	3.00E-01
4	**Wind velocity**	m/s	2.60	0%	2.60E+00
5	**Wave energy**				
	Wave height	m	0.50	0%	5.00E-01
6	**Rainfall**	m/yr	0.67	0%	6.67E-01
	Fraction of evapotranspired water		0.40	0%	4.00E-01
9	**Loss of topsoil (erosion, weathering)**				
	Agricultural Land Use area	ha	8.72E+02	0%	8.72E+02
	Erosion rate of farmed area	$g/m^2/yr$	1.72E+03	0%	1.72E+03
10	**Gasoline**	L/yr	1.03E+08	0%	1.03E+08
	Gasoline price	€/L	1.55	0%	1.55E+00
11	**Diesel and heavy fuel**	L/yr	4.19E+07	0%	4.19E+07
	Diesel price	€/L	1.45	0%	1.45E+00
12	**LPG (Liquid Petroleum Gas)**	L/yr	6.37E+06	0%	6.37E+06
	LPG price	€/L	0.75	0%	7.54E-01
13	**Heavy oil for domestic heating**	kg/yr	3.73E+07	0%	3.73E+07
	Heavy oil price	€/l	1.35	0%	1.35E+00
14	**Natural gas**	m^3/yr	2.36E+08	0%	2.36E+08
	Natural gas price	€/m^3	0.76	0%	7.60E-01
15	**Electricity**	kWh/yr	2.82E+09	0%	2.82E+09
	Electricity price	€/kWh	0.23	0%	2.26E-01
16	**Water (from acqueduct)**	m^3/yr	5.62E+07	0%	5.62E+07
	Water price	€/m^3	1.18	0%	1.18E+00
17	**Food items**				
17a	**Fish**	kg/yr	2.00E+07	0%	2.00E+07
	Fish price	€/kg	7.10	0%	7.10E+00
17b	**Meat**	kg/yr	6.89E+07	0%	6.89E+07
	Meat price	€/kg	3.44	0%	3.44E+00
17c	**Fruits and Vegetables price**	kg/yr	1.69E+08	0%	1.69E+08
	Fruits and Vegetables price	€/kg	0.59	0%	5.85E-01
17d	**Milk, cheese and other derivatives**	kg/yr	8.22E+07	0%	8.22E+07
	Milk, cheese and other derivatives price	€/kg	5.15	0%	5.15E+00
17e	**Cereals and derivatives**	kg/yr	1.48E+08	0%	1.48E+08
	Cereals and derivatives price	€/kg	0.14	0%	1.44E-01
17f	**Wine and alcoholics**	l/yr	6.59E+07	0%	6.59E+07
	Wine and alcoholics price	€/l	1.80	0%	1.80E+00
17g	**Olive and seed oils**	kg/yr	1.77E+07	0%	1.77E+07
	Olive and seed oils price	€/kg	2.64	0%	2.64E+00
18	**Machinery**				
18a	**Cars**	item/yr	1.25E+04	0%	1.25E+04
	Average car price	€/item	7189.00	0%	7.19E+03
18b	**Motorcycles**	item/yr	5.16E+03	0%	5.16E+03
	Average motorcycle price	€/item	2568.00	0%	2.57E+03
18c	**Buses**	item/yr	1.17E+02	0%	1.17E+02
	Average bus price	€/item	102700.00	0%	1.03E+05
18d	**Trucks**	item/yr	1.50E+03	0%	1.50E+03
	Average truck price	€/item	23621.00	0%	2.36E+04
18e	**Public Buses**	item/yr	9.80E+01	0%	9.80E+01
	Average public bus price	€/item	246480.00	0%	2.46E+05
18f	**Trams**	item/yr	4.81E+00	0%	4.81E+00
	Average tram price	€/item	308100.00	0%	3.08E+05

#	Item	Unit	Value	Variation	Sensitivity Adjusted Value
18g	**Trolleybuses**	item/yr	9.42E+00	0%	9.42E+00
	Average trolleybus price	€/item	410800.00	0%	4.11E+05
18h	**Subway wagon**	item/yr	5.77E+00	0%	5.77E+00
	Average subway wagon price	€/item	1027000.00	0%	1.03E+06
19	**Steel and iron**	kg/yr	4.19E+08	0%	4.19E+08
	Steel and iron price	€/kg	0.11	0%	1.13E-01
20	**Copper**	kg/yr	2.69E+06	0%	2.69E+06
	Copper price	€/kg	1.67	0%	1.67E+00
21	**Aluminium**	kg/yr	2.40E+07	0%	2.40E+07
	Aluminium price	€/kg	0.10	0%	1.03E-01
22	**Cement (Portland)**	kg/yr	5.32E+08	0%	5.32E+08
	Cement (Portland) price	€/kg	0.06	0%	6.16E-02
23	**Rocks and Sediments for building sector**	kg/yr	1.45E+11	0%	1.45E+11
	Rocks and Sediments for building sector price	€/kg	0.01	0%	1.03E-02
24	**Glass**	kg/yr	6.49E+07	0%	6.49E+07
	Glass price	€/kg	0.53	0%	5.34E-01
25	**Plastics**	kg/yr	1.45E+08	0%	1.45E+08
	Plastics price	€/kg	1.66	0%	1.66E+00
26	**Asphalt**	kg/yr	3.36E+07	0%	3.36E+07
	Asphalt price	€/kg	0.04	0%	4.11E-02
27	**Chemicals**	kg/yr	3.27E+07	0%	3.27E+07
	Chemicals price	€/kg	0.72	0%	7.19E-01
28	**Wood**	cm^3/yr	2.80E+08	0%	2.80E+08
	Wood price	€/cm^3	0.27	0%	2.67E-01
29	**Textiles**	kg/yr	1.42E+07	0%	1.42E+07
	Textiles price	€/kg	4.48	0%	4.48E+00
30	**Paper and derivatives**	kg/yr	1.86E+08	0%	1.86E+08
	Paper and derivatives price	€/kg	0.76	0%	7.60E-01
31	**Fertilizers**	kg/yr	2.04E+05	0%	2.04E+05
	Fertilizers price	€/kg	0.51	0%	5.14E-01
32	**Electric equipment**				
32a	**TV**	item/yr	8.65E+05	0%	8.65E+05
	TV price (average)	€/item	205.00	0%	2.05E+02
32b	**PC**	item/yr	2.83E+05	0%	2.83E+05
	PC price (average)	€/item	667.55	0%	6.68E+02
32c	**Cellphones**	item/inhab	1.55E+06	0%	1.55E+06
	Cellphone price (average)	€/item	184.86	0%	1.85E+02
33	**Human labor**				
	Total applied labor	number/yr	1.25E+04	0%	1.25E+04
34	**Tourism**				
	Number of visitors	number/yr	9.18E+05	0%	9.18E+05
	Total overnight stays (presence in hotels)	number/yr	2.16E+06	0%	2.16E+06
Products					
	Population	person/yr	9.61E+05	0%	9.61E+05
	GDP	€/yr	1.58E+10	0%	1.58E+10

Figure 7 – Urban Performance Calculator inventory related to the City of Napoli case study (input flows are highlighted in blue and economic values of input flows are highlighted in red).

The built inventory is used in order to perform the ex-ante LCA analysis needed to identify the relevant hotspots for the investigated system. The functional unit chosen for the LCA of Napoli urban metabolism is 1 m^2 (but could be chosen differently as "one thousand persons" or "one million Euro GDP" in a given year), whilst the selected system boundary is shown in Figure 8 including all inputs and outputs within the municipality of Napoli.

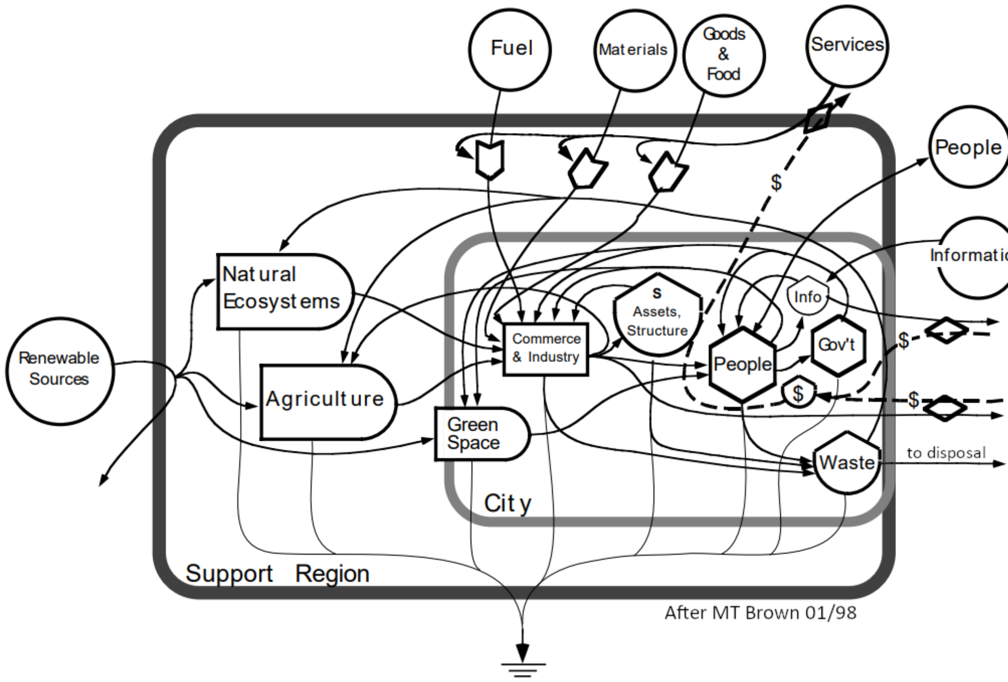


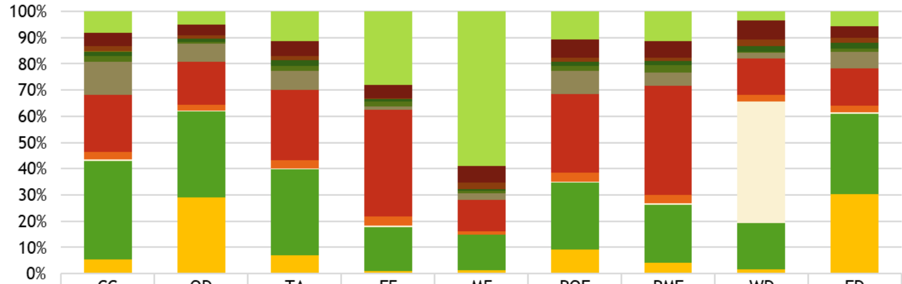
Figure 8 – System boundary of urban system.

Table 5 shows the LCA impact categories explored in this study. The LCA impact assessment has been performed by means of LCA software SimaPro 8.2.0 and the ReCiPe Midpoint hierarchist (H) impact assessment method v. 1.12 (Goedkoop, 2013). In order to ascertain the environmental load of Napoli urban system, the impact assessment has been based on characterization diagrams showing the breakdown into different impact sources. In this way the main hotspots for each investigated impact category and for the whole urban metabolism has been assessed.

Table 5 – LCA impact categories (ReCiPe Midpoint (H)).

Impact category	Abbreviation	Unit
Climate change	CC	kg CO_2 eq
Ozone depletion	OD	kg CFC-11 eq
Terrestrial acidification	TA	kg SO_2 eq
Freshwater eutrophication	FE	kg P eq
Marine eutrophication	ME	kg N eq
Photochemical oxidant formation	POF	kg NMVOC eq
Particulate matter formation	PMF	kg PM_{10} eq
Water depletion	WD	m^3
Fossil depletion	FD	kg oil eq

In Figure 9, the different contributions of each input flow are shown. As clearly appears, the main contributors are electricity (sharing about 25% of impacts as average value among all investigated impact categories), followed by metals (24%), electronics (16%) and fuels (10%) input flows.



	CC	OD	TA	FE	ME	POF	PMF	WD	FD
Electronics	8%	5%	11%	28%	59%	11%	11%	3%	6%
Fertilizers	0%	0%	0%	0%	0%	0%	0%	0%	0%
Paper	5%	4%	6%	5%	7%	7%	6%	7%	4%
Textiles	2%	1%	2%	0%	2%	1%	1%	3%	2%
Wood	0%	0%	0%	0%	0%	0%	0%	0%	0%
Chemicals	2%	1%	2%	1%	1%	2%	2%	2%	2%
Plastics	2%	1%	2%	2%	1%	2%	3%	0%	1%
Building materials	13%	7%	7%	1%	2%	9%	5%	2%	6%
Metals	22%	17%	27%	41%	12%	30%	42%	14%	14%
Transports	3%	2%	3%	4%	1%	3%	3%	3%	3%
Water	1%	0%	1%	1%	0%	1%	1%	46%	0%
Electricity	37%	33%	33%	17%	13%	25%	22%	18%	31%
Fuels	5%	29%	7%	1%	1%	9%	4%	2%	30%

Figure 9 – Characterization graph shows the relative contribution of the main input flows to the total burdens of the urban system of Napoli.

Once the hotspots are identified, EMA analysis of the urban system of Naples is performed, through spreadsheet-based calculation. The excel spreadsheets were constructed according to the specifications in Chapter 1. Once the input flows are properly modified in the right form (in the Calculation spreadsheet), they are multiplied by the specific UEVs (from the Emergy intensities spreadsheet) to obtain the total Emergy U, as illustrated in Figure 10.

When the final EMA indicators are calculated, the following three different scenarios are explored, by replacing the more impacting inflows over the resource supply chain to the urban system:

1. **Business As Usual (BAU) scenario**, evaluating the system as it is, with focus on the sensitivity of results to uncertainty of input and output data as well as to the willingness to apply a wise and rational use of resources (e.g., better use of existing techniques, waste prevention, "switch the light off when exiting the room" solutions) , in order to better understand the system's behavior and impacts before any decision is made). The random variation considered in this scenario is between -10% and +10%, in order to show the sensitivity of results, but different ranges may be selected for each resource input depending on the specific strategy;

2. **Technology-based Efficiency Improvement (TEI),** to suggest conservative improvements of the investigated level through energy and material technological efficiency, according to the LCA approach (e.g., by considering a reduction of the main energy and material input flows through technological innovation, such as design, cohibentation, light emission diode-LED technology, heat pumps instead of conventional heating systems, new materials such as graphene and others - these may have a higher emergy cost, but be able to provide a comparatively larger benefit). The random variation considered in this scenario is between -20% and 0%, i.e. assumed and planned decrease of resource demand.

3. **Eco-Efficiency Implementation (EEI),** i.e. achievable improvements of the environmental sustainability by substituting energy and material hotspots with renewable or less environmental costly input flows according to the EMA approach (less specific emergy UEV, such as photovoltaic electricity instead of fossil powered electricity; use of recycled materials; use of resources with lower emergy intensity even if still non-renewable). Technology-based Efficiency Improvement and Eco-efficiency can be applied separately to each investigated case and level, or even together to detect the potential for further improvement. The random variation considered in this scenario is between -10% and -5%.

# (*)	Items	Units	Raw amount	Transformity (seJ/unit)	Emergy (seJ/yr)	% of Emergy (with L&S)	% of Emergy (without L&S)
Renewable Input (locally available)							
Global tripartite							
1	Sun insolation	J/yr	3.18E+18	1.00E+00	3.18E+18		
2	Geothermal heat	J/yr	2.35E+14	4.90E+03	1.15E+18		
3	Tidal energy	J/yr	2.97E+14	3.09E+04	9.18E+18		
	Sum of tripartite				**1.35E+19**	0%	0%
Secondary and tertiary sources							
4	Wind	J/yr	1.11E+15	8.00E+02	8.88E+17		
5	Wave energy	J/yr	3.80E+16	4.20E+03	1.59E+20		
6	Rain, chemical potential energy	J/yr	1.42E+15	7.00E+03	9.96E+18		
7	Runoff, geopotential energy	J/yr	7.82E+12	1.28E+04	1.00E+17		
8	Runoff, chemical potential	J/yr	2.21E+11	2.13E+04	4.70E+15		
	Largest of Secondary and tertiary sources				**1.59E+20**	1%	2%
Nonrenewable Input (locally available)							
9	Top soil (erosion, wheathering)	kg/yr	4.50E+05	1.84E+11	**8.28E+16**	0%	0%
Imported Input							
10	Gasoline	J/yr	3.40E+15	1.48E+05	**5.03E+20**	3%	6%
11	Diesel and heavy fuel	J/yr	1.50E+15	1.43E+05	**2.14E+20**	1%	2%
12	LPG (Liquid Petroleum Gas)	J/yr	1.49E+14	1.41E+05	**2.10E+19**	0%	0%
13	Heavy oil for domestic heating	J/yr	1.59E+15	1.43E+05	**2.27E+20**	1%	3%
14	Natural gas	J/yr	9.30E+15	1.41E+05	**1.31E+21**	7%	15%
15	Electricity	J/yr	1.03E+16	2.13E+05	**2.20E+21**	12%	25%
	Electricity from PV	J/yr	0.00E+00	6.34E+04	**0.00E+00**	0%	0%
	Electricity from Eolics	J/yr	0.00E+00	4.48E+04	**0.00E+00**	0%	0%
16	Water (from acqueduct)	m3/yr	5.62E+07	1.00E+11	**5.62E+18**	0%	0%
17	Food items						
17a	Fish	g/yr	2.00E+10	1.02E+08	**2.04E+18**	0%	0%
17b	Meat	g/yr	6.89E+10	1.00E+10	**6.89E+20**	4%	8%
17c	Fruits and Vegetables price	g/yr	1.69E+11	3.90E+08	**6.57E+19**	0%	1%
17d	Milk, cheese and other derivatives	g/yr	8.22E+10	8.00E+09	**6.57E+20**	3%	7%
17e	Cereals and derivatives	g/yr	1.48E+11	3.30E+08	**4.88E+19**	0%	1%
17f	Wine and alcoholics	g/yr	5.95E+10	1.06E+09	**6.30E+19**	0%	1%
17g	Olive and seed oils	g/yr	1.63E+07	3.21E+11	**5.23E+18**	0%	0%
18	Machinery						
	Steel and iron fraction	g/yr	2.08E+09	2.65E+09	**5.52E+18**	0%	0%
	Plastic fraction	g/yr	4.02E+08	2.39E+09	**9.62E+17**	0%	0%
	Alluminum fraction	g/yr	2.21E+08	4.08E+07	**9.00E+15**	0%	0%
	Glass fraction	g/yr	6.52E+07	2.50E+09	**1.63E+17**	0%	0%
19	Steel and iron	g/yr	4.19E+11	2.65E+09	**1.11E+21**	6%	13%
20	Copper	g/yr	2.69E+09	5.78E+08	**1.56E+18**	0%	0%
21	Aluminium	g/yr	2.40E+10	4.08E+07	**9.80E+17**	0%	0%
22	Cement (Portland)	g/yr	5.32E+11	1.25E+09	**6.64E+20**	3%	8%
23	Rocks and Sediments for building sector	g/yr	2.90E+12	1.56E+06	**4.52E+18**	0%	0%
24	Glass	g/yr	6.49E+10	2.50E+09	**1.62E+20**	1%	2%
25	Plastics	g/yr	1.45E+11	2.39E+09	**3.48E+20**	2%	4%
26	Asphalt	g/yr	3.36E+10	2.39E+09	**8.02E+19**	0%	1%
27	Chemicals	g/yr	3.27E+10	2.10E+07	**6.86E+17**	0%	0%
28	Wood	g/yr	2.10E+08	7.32E+09	**1.54E+18**	0%	0%
29	Textiles	g/yr	1.42E+10	7.23E+09	**1.03E+20**	1%	1%
30	Paper and derivatives	g/yr	1.86E+11	4.82E+08	**8.99E+19**	0%	1%
31	Fertilizers	g/yr	2.04E+08	1.01E+11	**2.06E+19**	0%	0%
32	Electric equipment	g/yr	9.56E+08	4.95E+09	**4.73E+18**	0%	0%
33	Human labor	number/yr	1.25E+04	4.35E+16	**5.44E+20**	3%	
35	Annual Services in Urban System	€/yr	5.90E+09	1.66E+12	**9.79E+21**	51%	
	TOTAL EMERGY with Labor and Services				**1.91E+22**	100%	100%
	TOTAL EMERGY without Labor and Services				**8.77E+21**		
Output							
	Population	person/yr	9.61E+05				
	GDP	€/yr	1.58E+10				
	Inhabitants equivalent	person/yr	5.92E+03				

Figure 10 – Emergy spreadsheet from the UPC.

The first scenario (I-BAU) was developed considering a variation in the main impacting energy and material input flows considering a range of -10% and 10%. For the Napoli case study the selected hotspots are electricity, natural gas and steel & iron. In the second scenario (Technology-based Efficiency Improvement) a better use of the main contributors to the environmental burdens was suggested. For this reason the electricity input flow has been reduced in the range of -20% and 0% assuming replacement of a fraction of the lighting system by means of Light Emission Diodes (LED), which generally allow a lower consumption around 70%. The variation in the third scenario (Eco-Efficiency Implementation, EEI) has been related to the quality of the hotspot input flows. The electricity supporting the investigated urban system has been partially replaced by electricity coming from lower emergy intensity (UEV) sources (photovoltaic and wind), reducing the fossil fraction of the electricity mix of about 40%. The user can decide to replace a larger share of electricity coming from photovoltaic or wind sources, automatically lowering the fraction of electricity from the national mix.

According with the EUFORIE Prototype Tool illustrated in Chapter 1, Table 6 highlights the VBA code related to the variation in the UPC.

Table 6 – VBA code for the creation of 200 random values within a range. The same code (with proper cells numbers) is applied to the three different hotspots.

Range(Cells(10, 11), Cells(65536, 11)).ClearContents	***To clear the cells where results will be shown.***
a = Cells(7, 11).Value	***Variable a equal to value of input flow***
b = Cells(7, 12).Value	***Variable b equal to minimum of variation range***
c = Cells(7, 13).Value	***Variable c equal to maximum of variation range***
r = 0	***Random value variable***
t = 0	***Loop counting variable***
i = 10	***Start printing results from row 10***
Randomize	***Beginning of randomization function***
Do Until t > 200	***To obtain 200 different values***
r = WorksheetFunction.RandBetween(b, c)	***r is equal to a random value between the minimum and the maximum of the range***
r = r / 100	***Random value to percentage***
Cells(i, 12) = r	***Random value printed***
Cells(i, 11) = a + (a * r)	***Value of input flow times the random percentage and printed***
t = t + 1	***Counter increase by 1***
i = i + 1	***Move to next row***
Loop	***Loop for 200 times***

After the calculation of the total Emergy U for the urban system of Napoli, accounting for the variation of each hotspot alone and for the total variation of U when the hotspots vary all together, the last step consists in the construction of the interactive browser based application (Figure 11). This tool allows the stakeholders overviewing the results obtained so far, whit a set of buttons highlighting the differences between the built scenarios, with and without L&S, in term of total Emergy U, namely in terms of the total demand for environmental support by the system in the state determined by the scenario and the implemented variations. Other performance and sustainability indicators related to the emergy method can also be calculated and compared in a like manner.

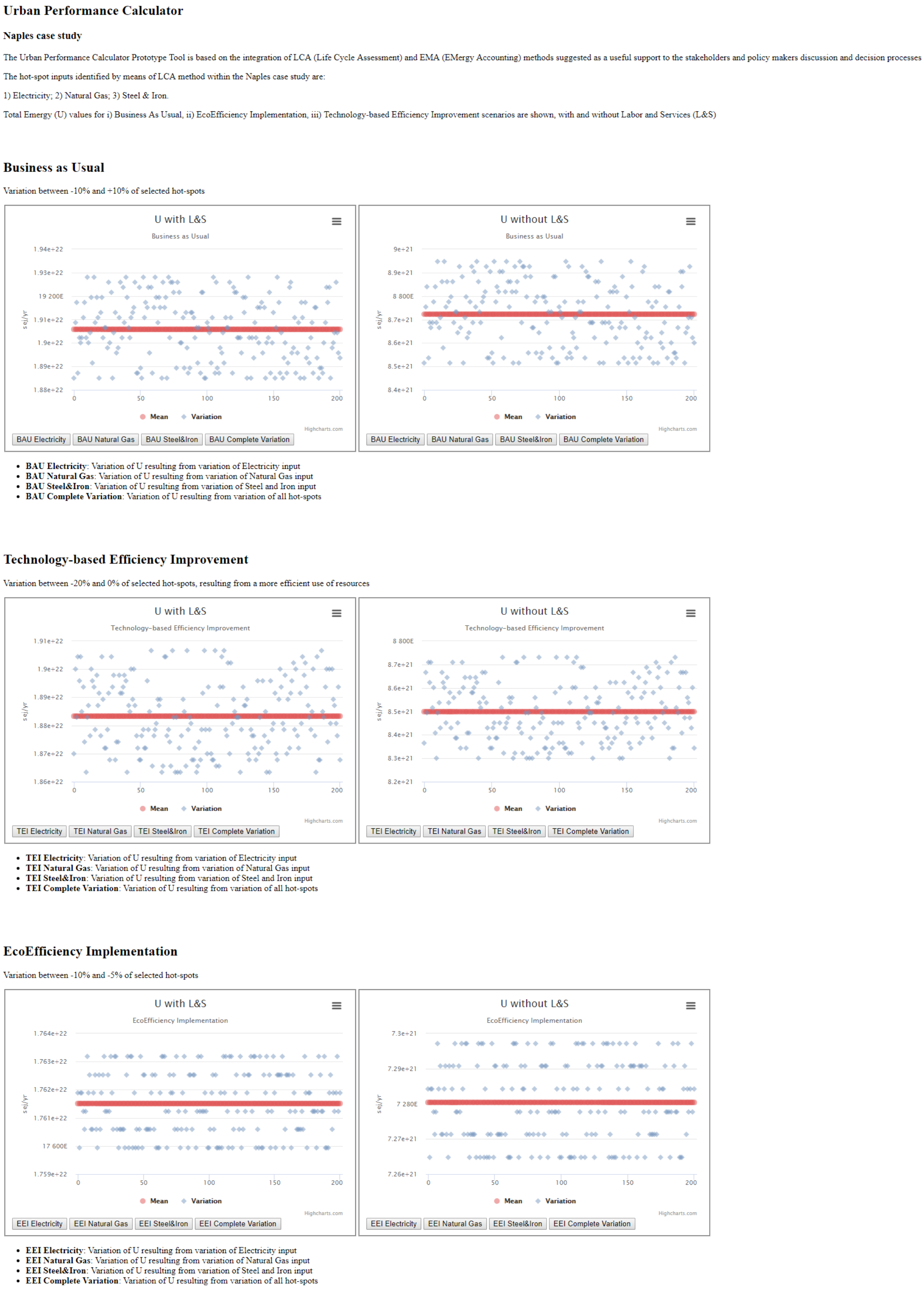


Figure 11 – The browser based tool Urban Performance Calculator.

The HTML code for the UPC, showed in Table 7, is based on the code presented in Table 3, with proper modifications to adapt the code to the specific case study of the city of Napoli.

Table 7 – HTML code for the Urban Performance Calculator.

<html lang="en" > <head> <meta charset="UTF-8"> <title>Urban Performance Calculator</title> </head> <body>	***Start of the html page with title***
style type="text/css"> #BAUwith {float:left;} #BAUwithout {float:left;} #EEIwith {float:left;} #EEIwithout {float:left;} #TEIwith {float:left;} #TEIwithout {float:left;} </style>	***Code to define the position of the graphs within the page***
<script src='http://cdnjs.cloudflare.com/ajax/libs/jquery/2.1.3/jquery.min.js'></script> <script src='https://code.highcharts.com/highcharts.js'></script> <script src= 'http://code.highcharts.com/modules/exporting.js' ></script> <!—optional Module –> <script src= 'http://code.highcharts.com/modules/offline-exporting.js'></script>	***Code to call Java and Highcharts scripts needed for the Urban Performance Calculator functioning***
Urban Performance Calculator Naples case study The Urban Performance Calculator Prototype Tool is based on the integration of LCA (Life Cycle Assessment) and EMA (EMergy Accounting) methods suggested as a useful support to the stakeholders and policy makers discussion and decision processes The hot-spot inputs identified by means of LCA method within the Naples case study are: 1) Electricity; 2) Natural Gas; 3) Steel & Iron. Total Emergy (U) values for i) Business As Usual, ii) EcoEfficiency Implementation, iii) Technology-based Efficiency Improvement scenarios are shown, with and without Labor and Services (L&S) 	***Generic text section explaining the tool***

```
<h2>Business as Usual</h2>
<p>Variation between -10% and +10% of selected hot-spots</p>

<fieldset id="BAUwith">
<div id="containerA" style="width: 600px; height: 400px;"></div>
<button id="button">BAU Electricity</button>
<button id="button2">BAU Natural Gas</button>
<button id="button3">BAU Steel&Iron </button>
<button id="button4">BAU Complete Variation</button>
<script  src="script1.js"></script>
</fieldset>

<fieldset id="BAUwithout">
<div id="containerB" style="width: 600px; height: 400px;"></div>
<button id="button5">BAU Electricity</button>
<button id="button6">BAU Natural Gas</button>
<button id="button7">BAU Steel&Iron </button>
<button id="button8">BAU Complete Variation</button>
<script  src="script2.js"></script>

</fieldset>
<br style="clear:both" />
<ul>
<li><strong>BAU Electricity</strong>: Variation of U resulting from variation of Electricity input</li>
<li><strong>BAU Natural Gas</strong>: Variation of U resulting from variation of Natural Gas input</li>
<li><strong>BAU Steel&amp;Iron</strong>: Variation of U resulting from variation of Steel and Iron input</li>
<li><strong>BAU Complete Variation</strong>: Variation of U resulting from variation of all hot-spots</li>
</ul>

<br style="clear:both" />
<br>
<br>
```

Section of code relative to the BAU scenario. The first lines of code of the “with L&S” and of the “wthout L&S” fieldsets are to define the containers (i.e. the dedicated spaces) for the charts and the buttons needed to switch between the different assumptions. The last line before closing the fieldsets is to call the script that builds the chart.

Lines before and after the fieldsets are generic text explaining the different assumption

	s within the BAU scenario.

```
<h2>Technology-based Efficiency Improvement</h2>
<p>Variation between -20% and 0% of selected hot-spots, resulting from a more efficient use of resources</p>

<fieldset id="TEIwith" >
<div id="containerE" style="width: 600px; height: 400px;"></div>
<button id="button17">TEI Electricity</button>
<button id="button18">TEI Natural Gas</button>
<button id="button19">TEI Steel&Iron</button>
<button id="button20">TEI Complete Variation</button>
<script  src="script5.js"></script>
</fieldset>

<fieldset id="TEIwithout" >
<div id="containerF" style="width: 600px; height: 400px;"></div>
<button id="button21">TEI Electricity</button>
<button id="button22">TEI Natural Gas</button>
<button id="button23">TEI Steel&Iron</button>
<button id="button24">TEI Complete Variation</button>
<script  src="script6.js"></script>
</fieldset>
<br style="clear:both" />
<ul>
<li><strong>TEI Electricity</strong>: Variation of U resulting from variation of Electricity input</li>
<li><strong>TEI Natural Gas</strong>: Variation of U resulting from variation of Natural Gas input</li>
<li><strong>TEI Steel&amp;Iron</strong>: Variation of U resulting from variation of Steel and Iron input</li>
<li><strong>TEI Complete Variation</strong>: Variation of U resulting from variation of all hot-spots</li>
</ul>

<br style="clear:both" />
<br>
<br>
```

Section of code relative to the TEI scenario. The first lines of code of the “with L&S” and of the “wthout L&S” fieldsets are to define the containers (i.e. the dedicated spaces) for the charts and the buttons needed to switch between the different assumption s. The last line before closing the fieldsets is to call the script that builds the chart.

Lines before and after the fieldsets are generic text explaining the different assumption

	s within the TEI scenario.

```html
<h2>EcoEfficiency Implementation</h2>
<p>Variation between -10% and -5% of selected hot-spots</p>

<fieldset id="EEIwith" >
<div id="containerC" style="width: 600px; height: 400px;"></div>
<button id="button9">EEI Electricity</button>
<button id="button10">EEI Natural Gas</button>
<button id="button11">EEI Steel&Iron </button>
<button id="button12">EEI Complete Variation</button>
<script  src="script3.js"></script>
</fieldset>

<fieldset id="EEIwithout" >
<div id="containerD" style="width: 600px; height: 400px;"></div>
<button id="button13">EEI Electricity</button>
<button id="button14">EEI Natural Gas</button>
<button id="button15">EEI Steel&Iron</button>
<button id="button16">EEI Complete Variation</button>
<script  src="script4.js"></script>
</fieldset>
<br style="clear:both" />
<ul>
<li><strong>EEI Electricity</strong>: Variation of U resulting from variation of Electricity input</li>
<li><strong>EEI Natural Gas</strong>: Variation of U resulting from variation of Natural Gas input</li>
<li><strong>EEI Steel&amp;Iron</strong>: Variation of U resulting from variation of Steel and Iron input</li>
<li><strong>EEI Complete Variation</strong>: Variation of U resulting from variation of all hot-spots</li>
</ul>

<br style="clear:both" />
<br>
<br>
```

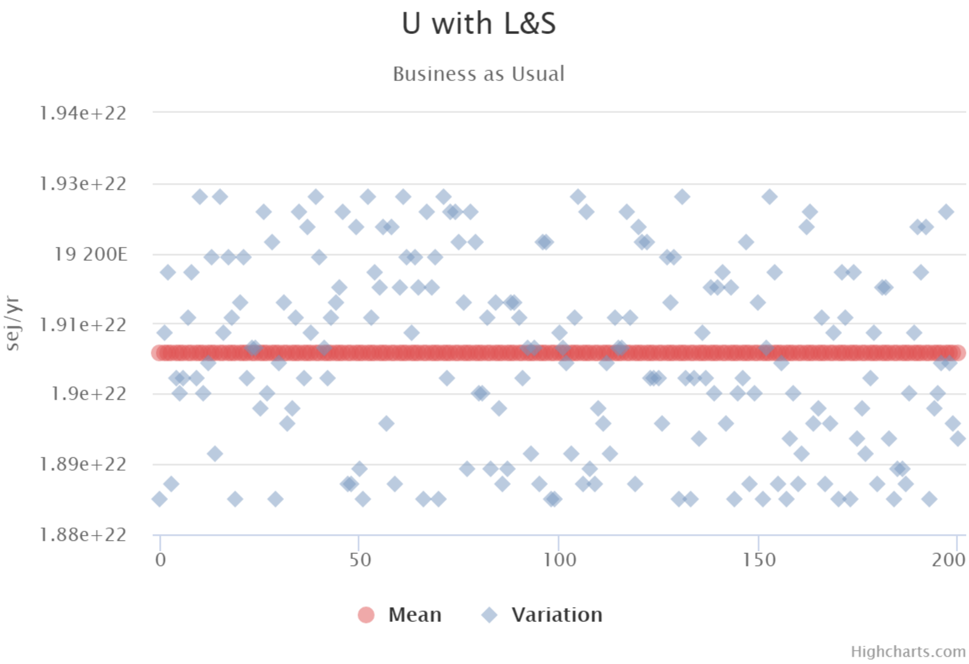
Section of code relative to the TEI scenario. The first lines of code of the “with L&S” and of the “wthout L&S” fieldsets are to define the containers (i.e. the dedicated spaces) for the charts and the buttons needed to switch between the different assumptions. The last line before closing the fieldsets is to call the script that builds the chart.

Lines before and after the fieldsets are generic text explaining the different assumption

	s within the TEI scenario.
</body>	***End of code.***
</html>	

The Java code needed for the tool to work is the same as described in Chapter 1, applied for every scenario and filled with the proper data and modifications needed to adapt it to the Napoli case study.

Figure 12 (a, b, c, d) highlights the resulting charts for the I-BAU scenario of the resulting total Emergy U for a) the variation of the Electricity input, b) the variation of the Natural Gas input, c) the variation of the Steel and Iron input, d) the variation of all the hotspots at once. The results achieved are already commented in EUFORIE D3.3. The I-BAU results highlights how the input data oscillations (between – 10% and 10%) due to statistical influence or not really significant decrease related to wise resource use awareness.



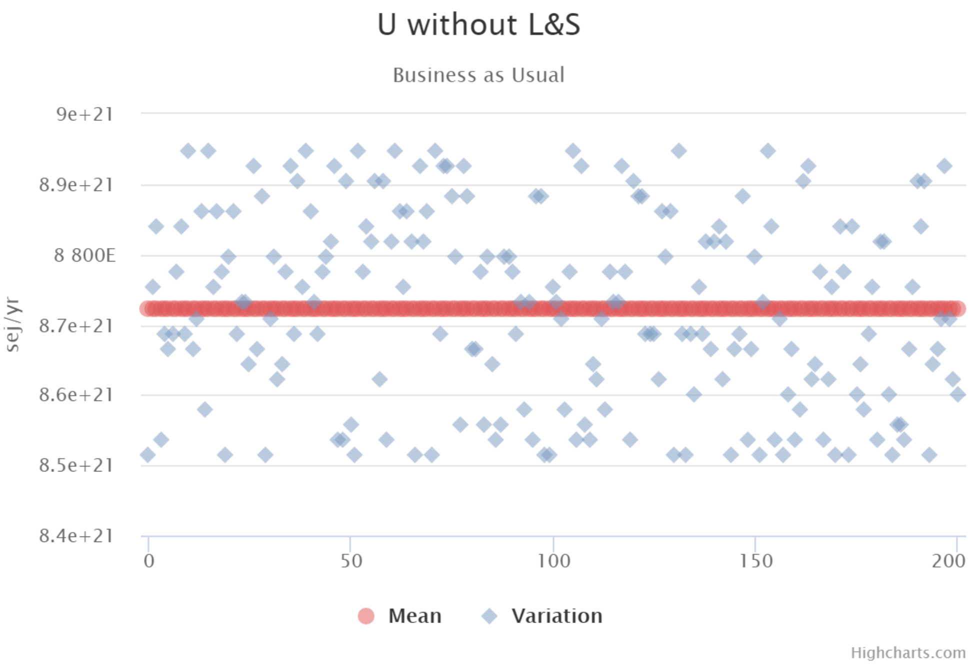
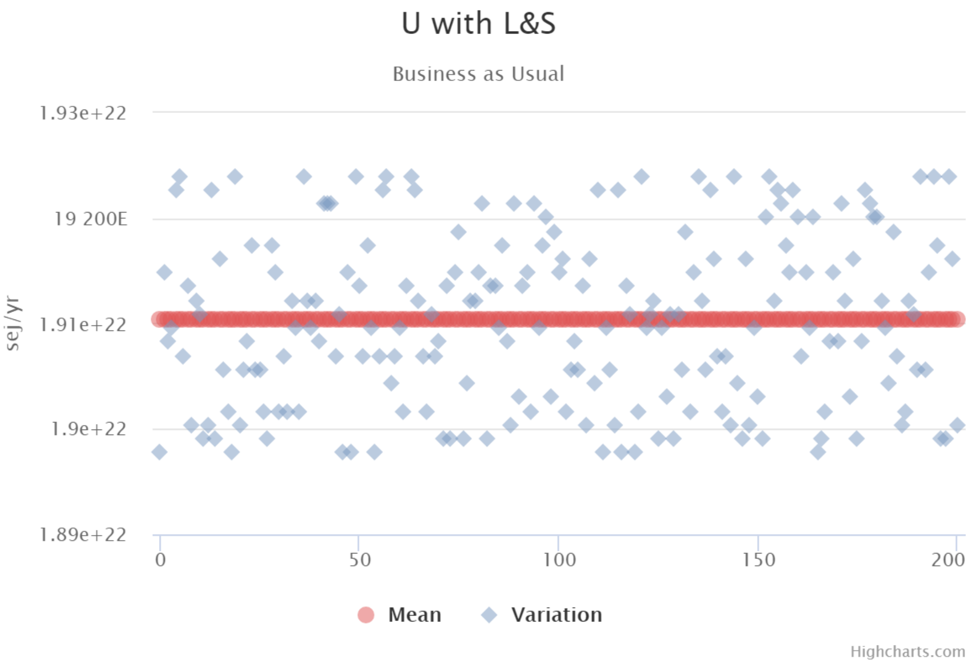


Figure 12-a – I-BAU variation charts of U related to variation of Electricity input.



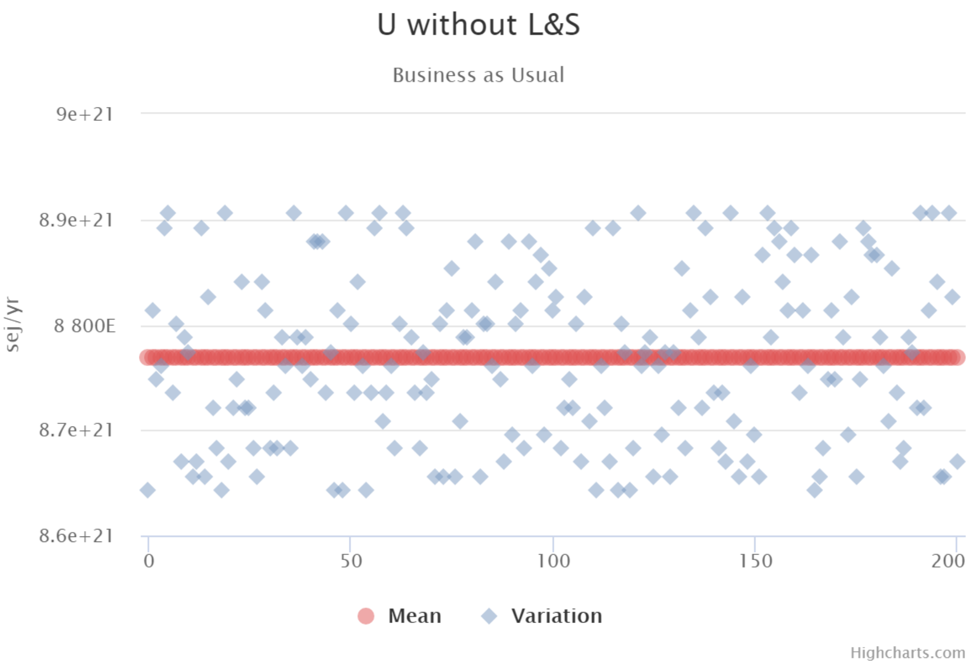
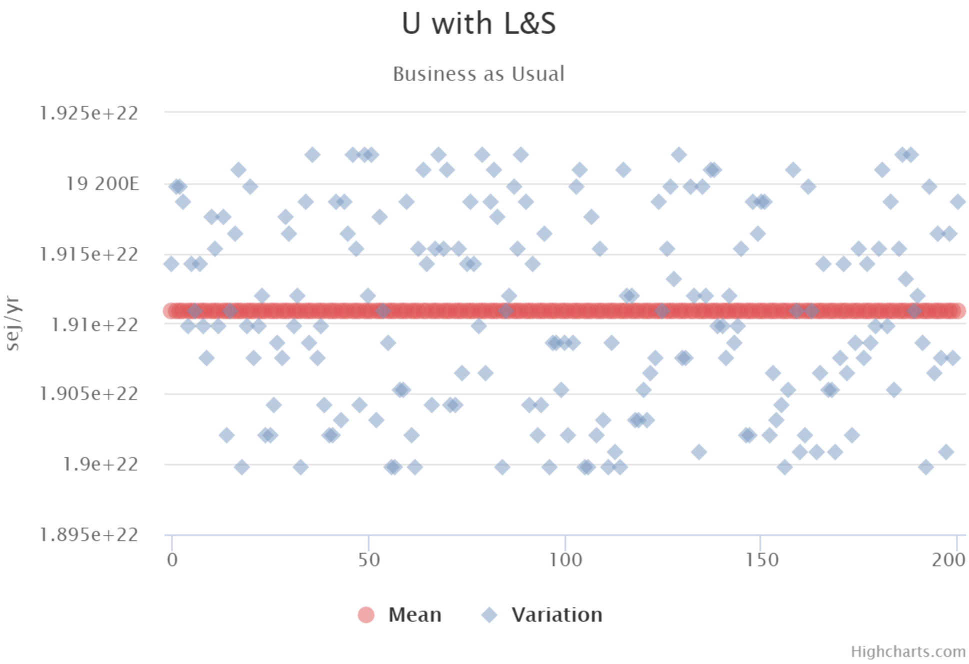


Figure 12-b – I-BAU variation charts of U related to variation of Natural gas input.



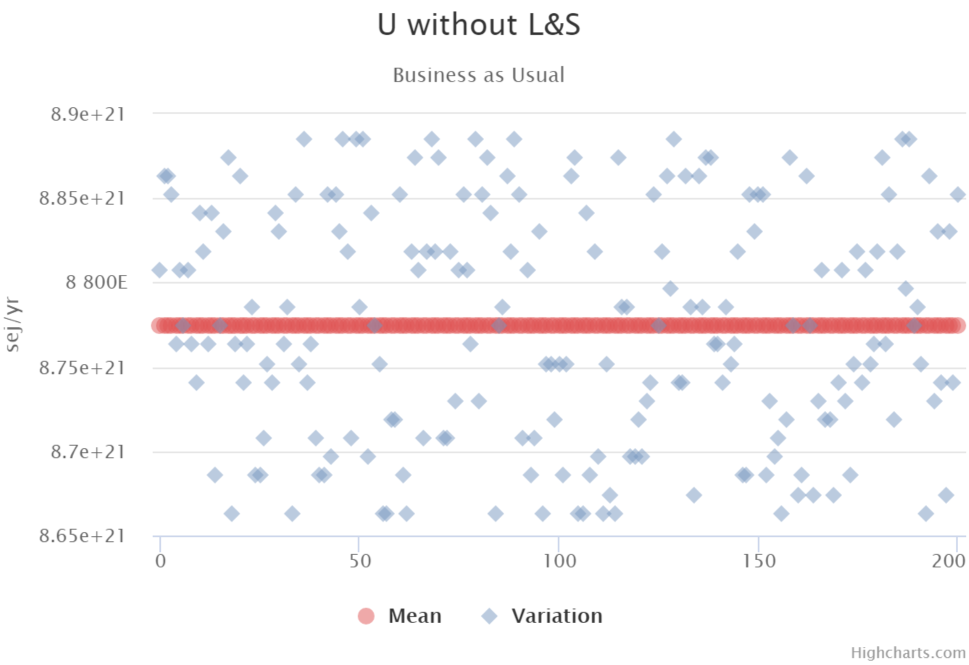
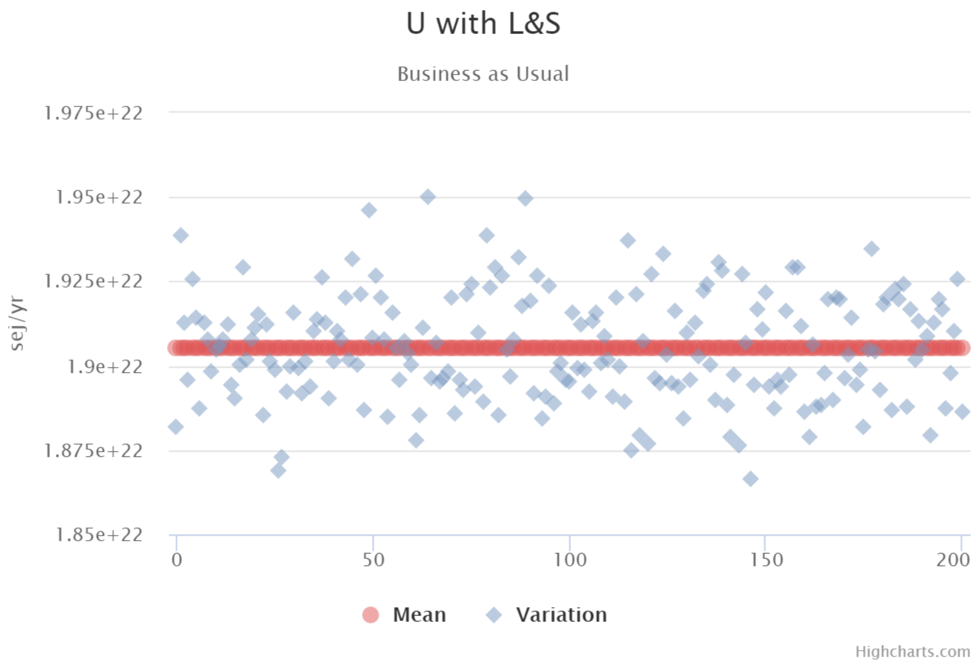


Figure 12-c – I-BAU variation charts of U related to variation of Steel & Iron input.



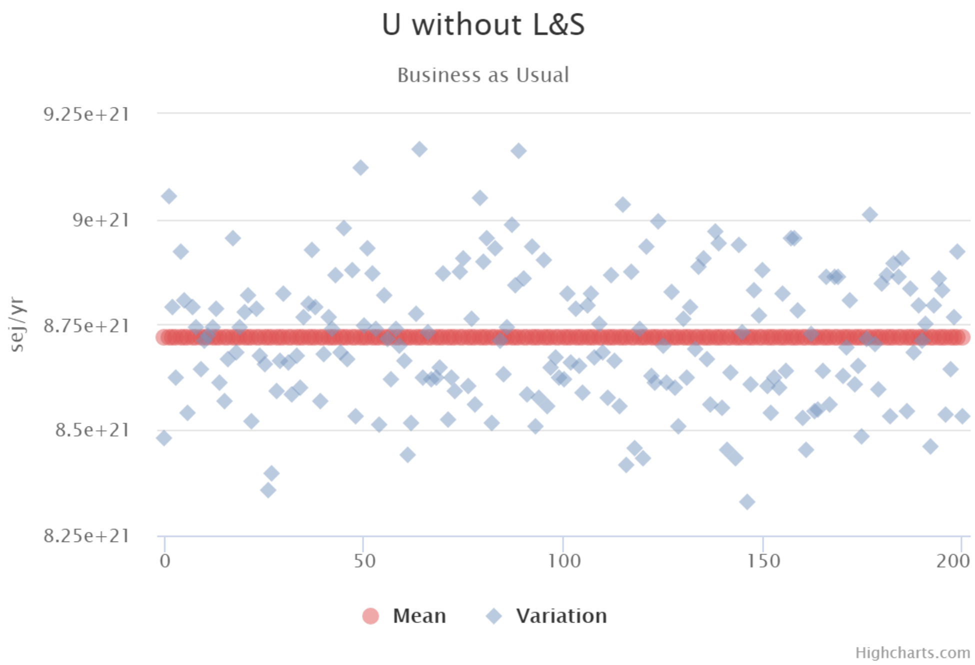


Figure 12-c – I-BAU variation charts of U related to variation of all hotspots together.

The results for I-BAU scenario do not show significant deviations in terms of Emergy indicators (EUFORIE D3.3) from the mean value calculated without any assumed variation. Therefore, this scenario can be considered as a benchmark for the comparison of the other scenarios proposed.

Figure 13 (a, b, c, d) shows the application of the UPC to the TEI scenario, underlining the calculated total Emergy U for a) the variation of the Electricity input, b) the variation of the Natural Gas input, c) the variation of the Steel and Iron input, d) the variation of all the hotspots at once. TEI involve a variation of the selected hotspots between -20% and 0%, assuming a technological improvement in the use of resources, as explained in EUFORIE D3.3. The results achieved when all hotspots variation is considered show, for TEI scenario, a relevant decrease (-56%) of the mean value of U without L&S (obtained through the VBA procedure - see Chapter 1), compared to I-BAU scenario. The comparison of U value with L&S between I-BAU and TEI does not show significant improvements (about 2%) due to the relevant weight of L&S Emergy flows on the total Emergy value U and the still limited variation of the selected hotspots.

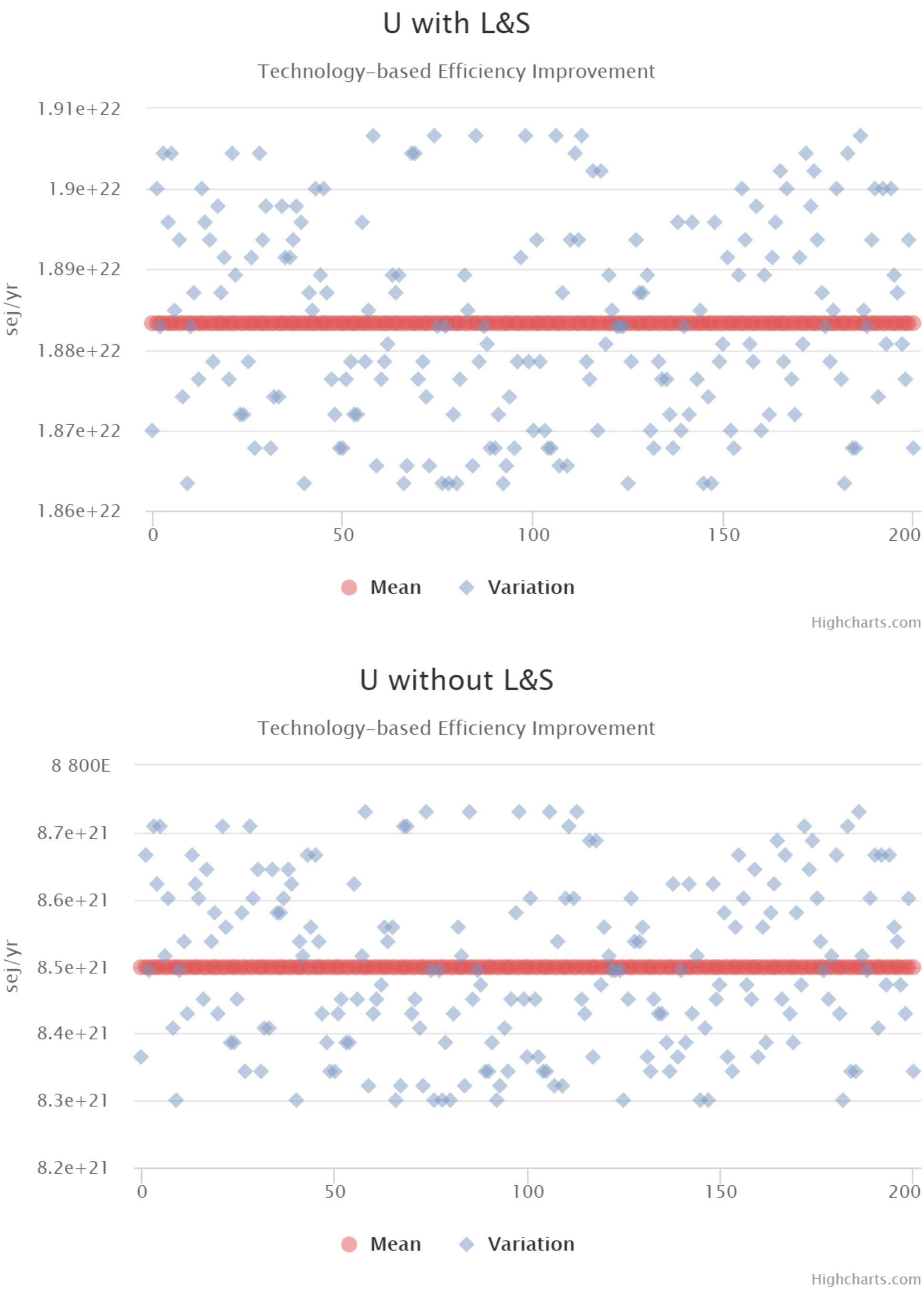
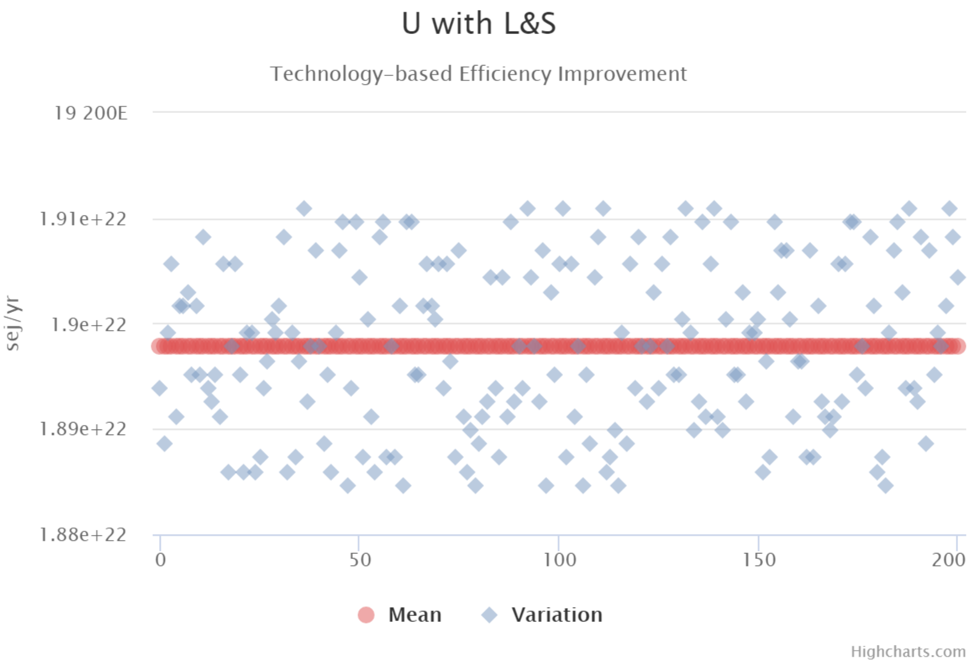


Figure 13-a – TEI variation charts of U related to variation of Electricity input.



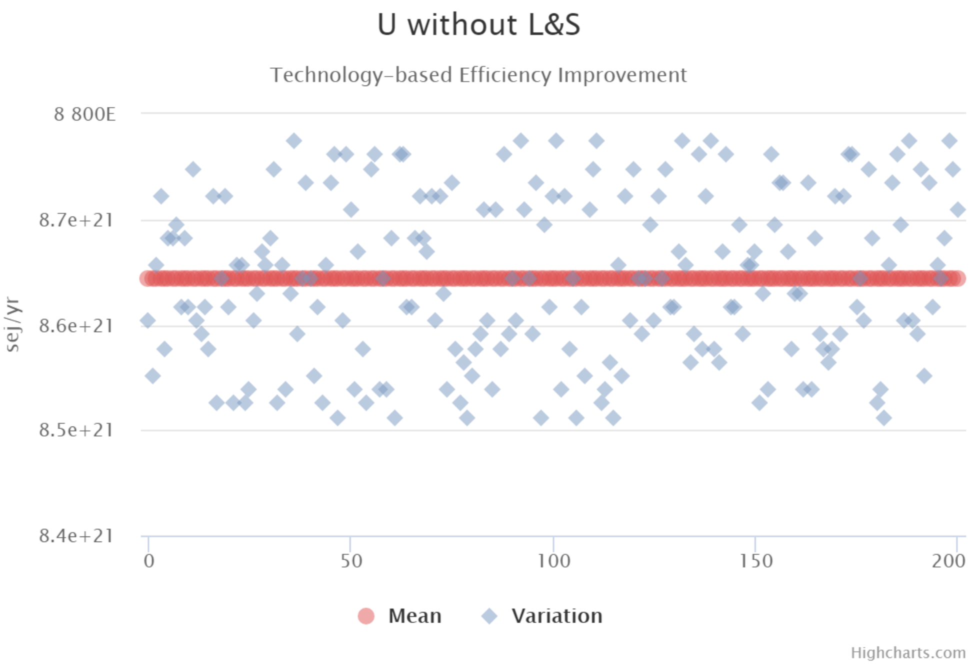
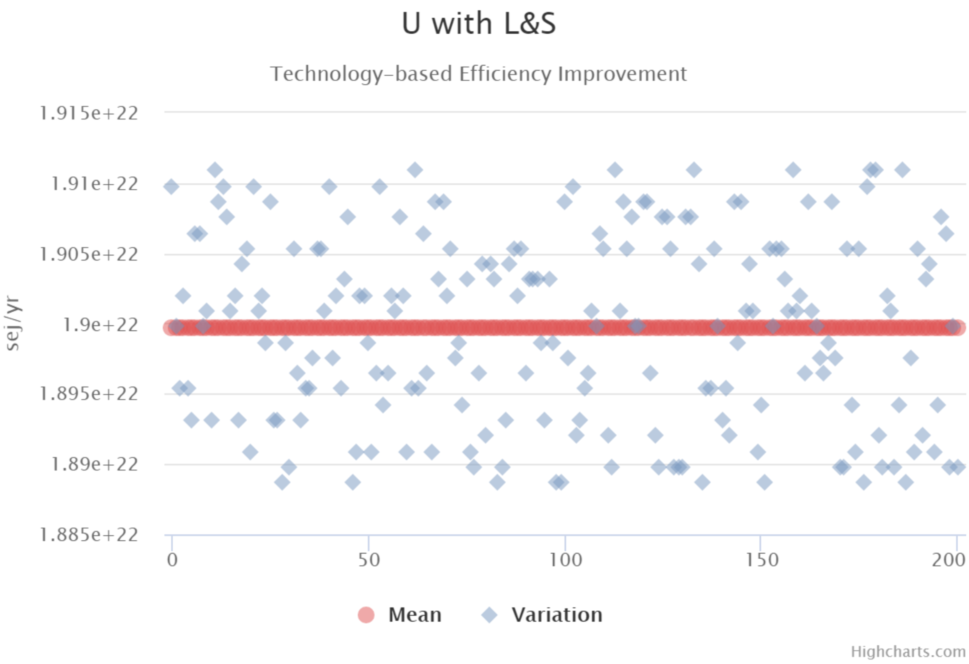


Figure 13-b – TEI variation charts of U related to variation of Natural gas input.



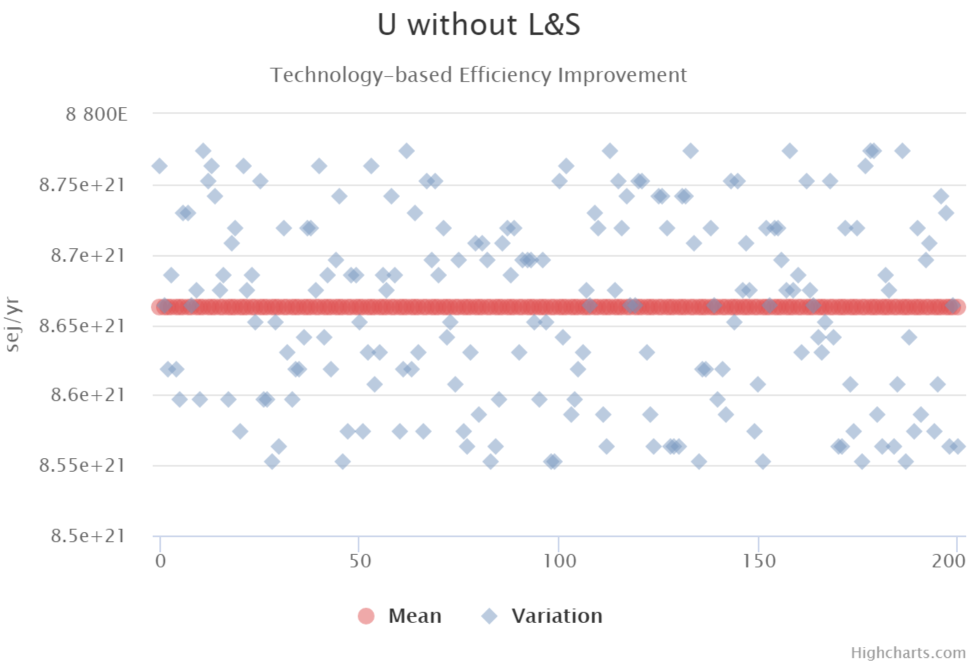
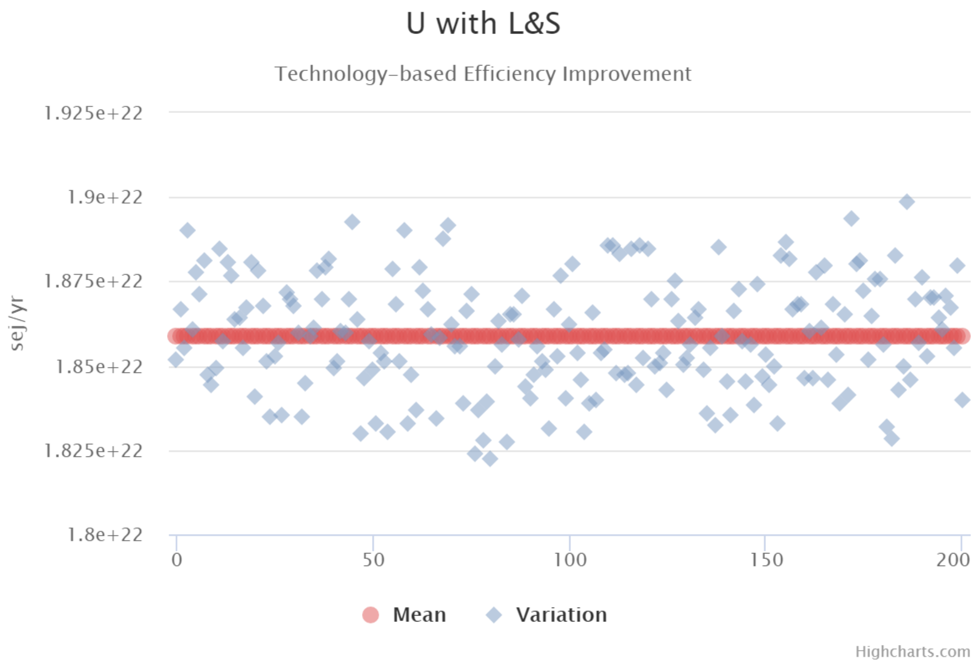


Figure 13-c – TEI variation charts of U related to variation of Steel & Iron input.



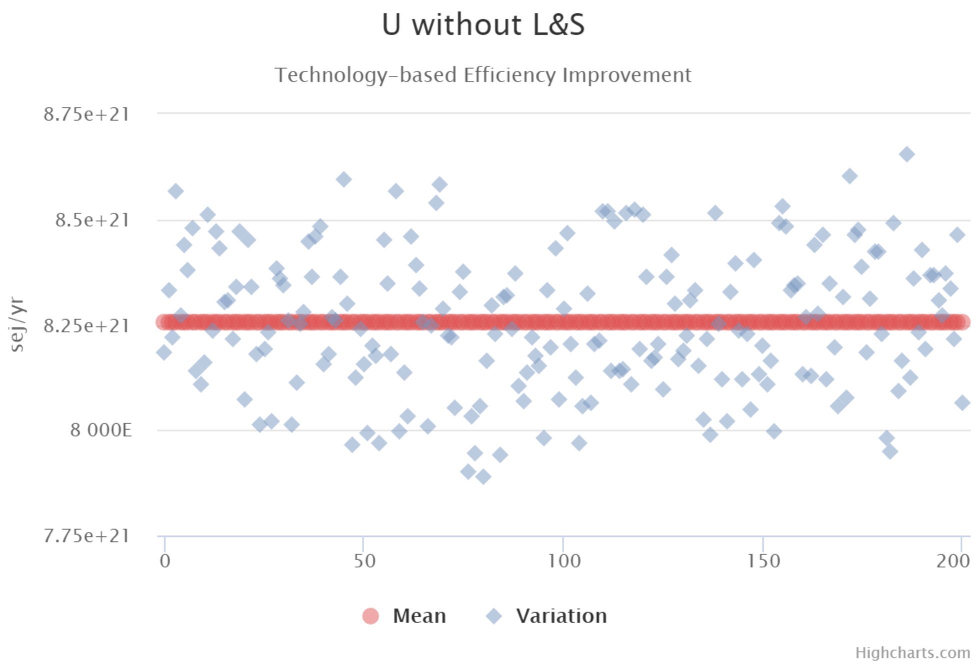
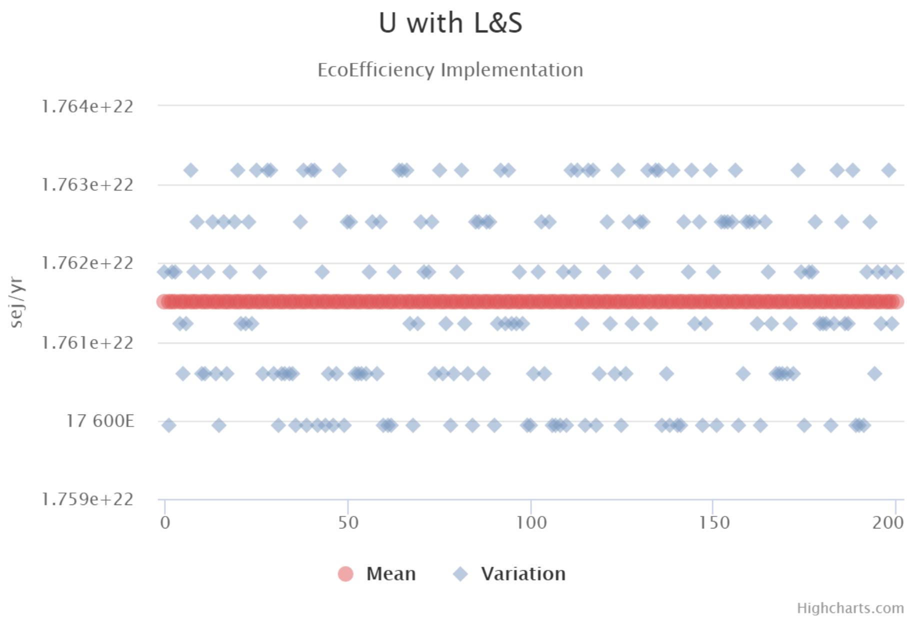


Figure 13-d – TEI variation charts of U related to variation of all hotspots together.

In Figure 14 (a, b, c, d) the results for the EEI scenario within the UPC are showed. As before, the charts display the U values with and without L&S related to a) the variation of the Electricity input, b) the variation of the Natural Gas input, c) the variation of the Steel and Iron input, d) the variation of all the hotspots at once. EEI scenario is characterized by a substitution of the common primary sources (fossil fuels and primary minerals) with more environmental sustainable secondary counterparts (electricity from natural sources, recycled materials, secondary minerals, bio-based chemicals and fuels, etc.). As specified in D3.3, in the EEI scenario the conventional electricity mix was integrated with a larger share coming from photovoltaics and wind; natural gas was substituted with biogas, and steel and iron was considered from recycle of scrap metals. The percentage of variation considered in EEI is between -10% and -5%. U values with L&S from EEI scenario compared with BAU scenario shows a reduction of about 17%, despite the weight of L&S. The latter is due to the substantial reduction of total Emergy U caused by the use of the UEVs with a lower value, because related to a more environmentally friendly secondary source, compared to the UEV values of primary sources. The reduction of U value without L&S is equal to 71%, showing how EEI scenario is an overview of how is possible to achieve a more environmental sustainability in the investigated system. Indeed, the use of recycled secondary materials, bio-based products (fuels, materials, chemicals) and in general a more efficient management of resources lead to a significant environmental improvement, according to the suggested conceptual framework of the Circular Economy (CE).



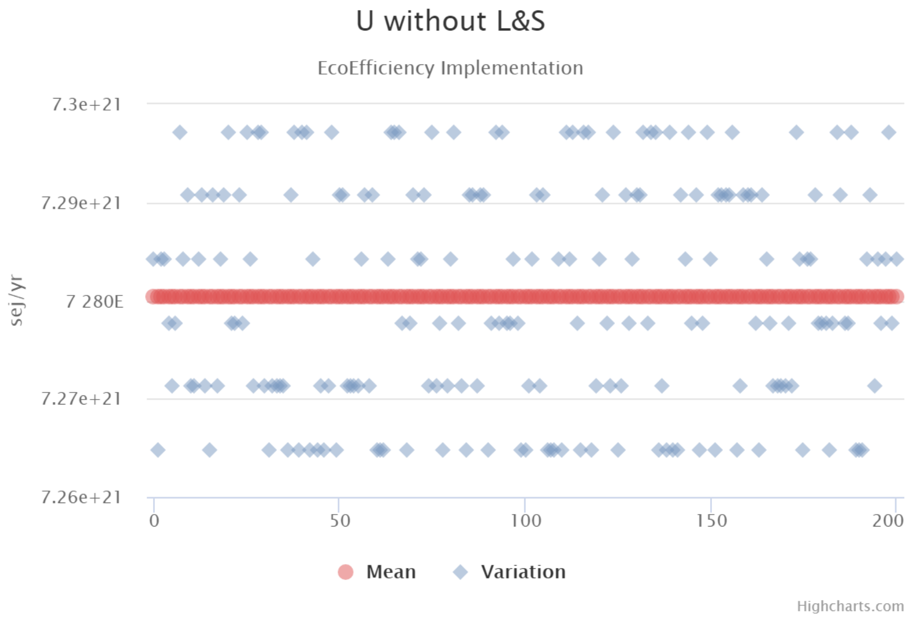
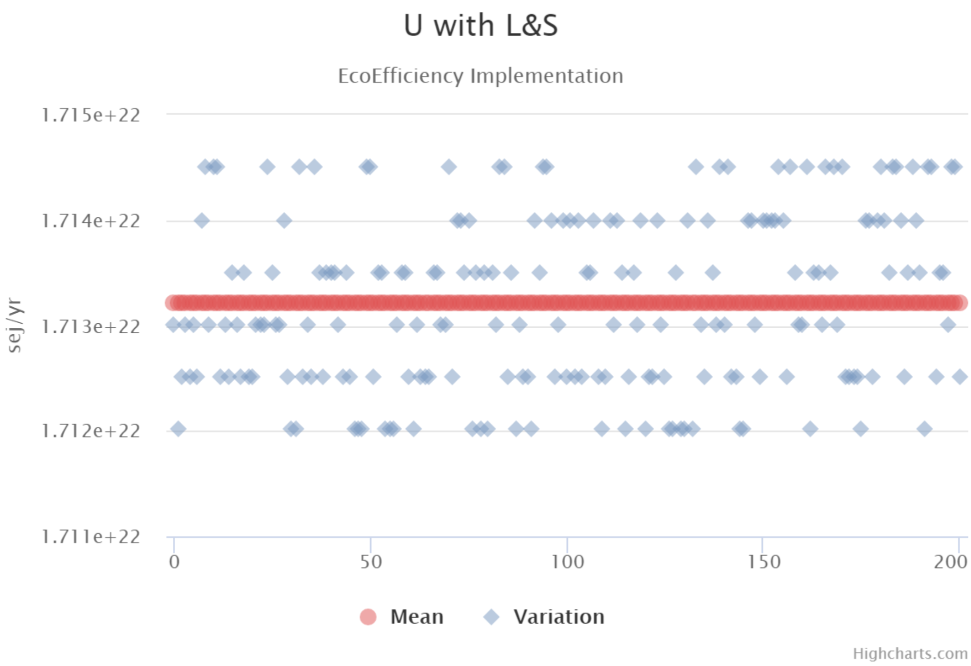


Figure 14-a – EEI variation charts of U related to variation of Electricity input.



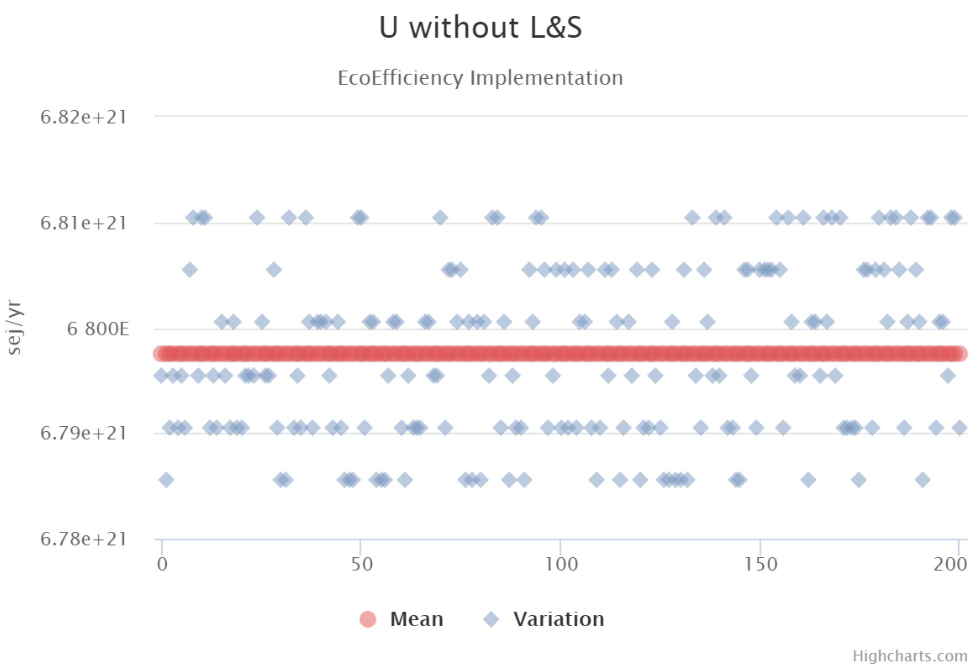
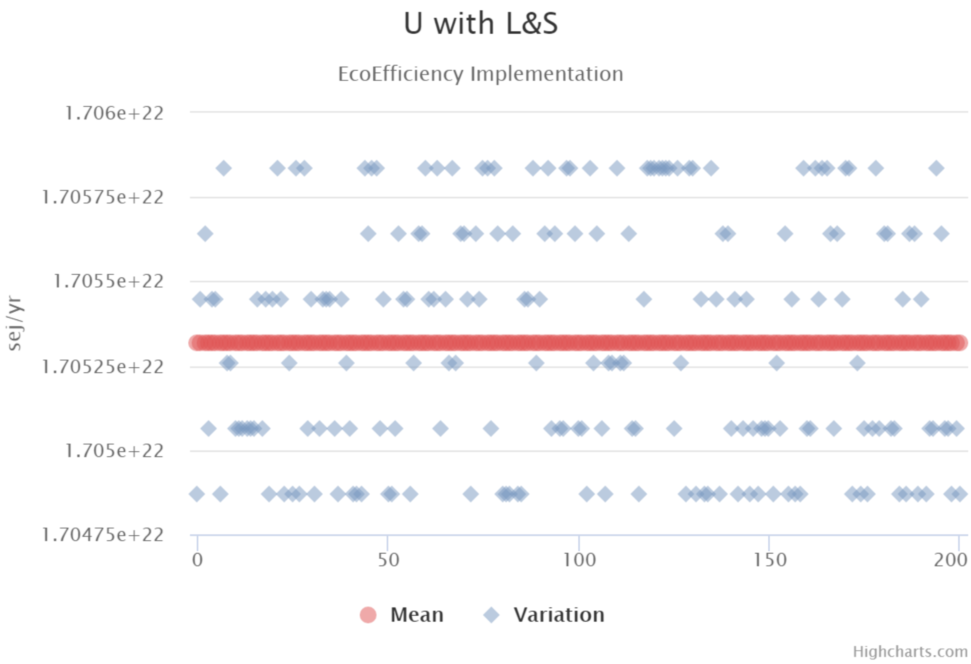


Figure 14-b – EEI variation charts of U related to variation of Natural gas input.



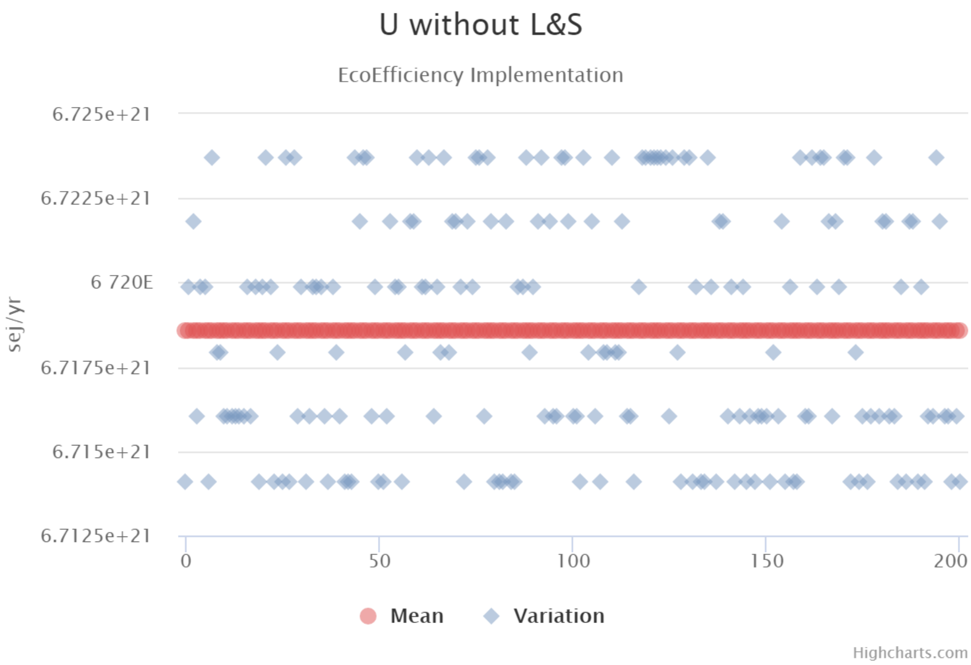
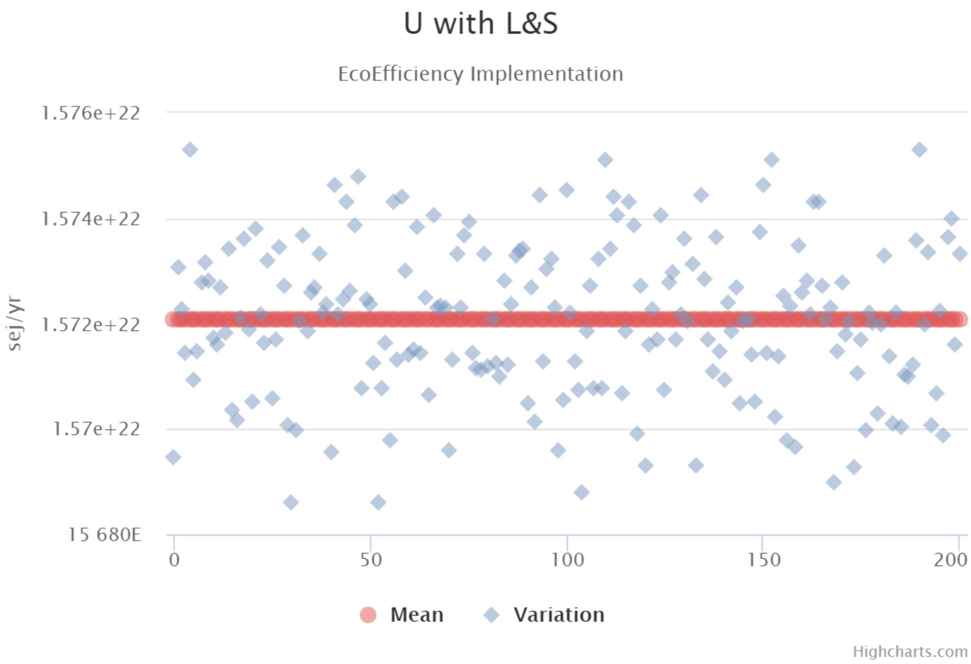


Figure 14-c – EEI variation charts of U related to variation of Steel & Iron input.



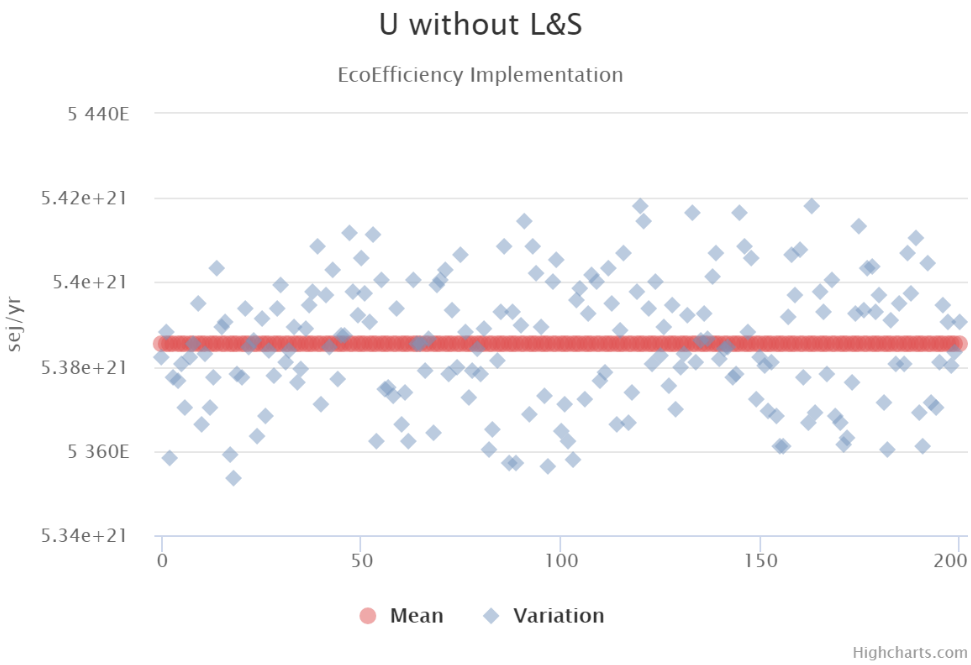


Figure 14-d – EEI variation charts of U related to variation of all hotspots together.

The outcome of the EUFORIE Prototype Tool is an assessment of the environmental performances, confirmed through an ex-post LCA analysis, for each obtained EMA scenario (I-BAU, TEI, EEI) in terms of: (i) less environmental impacts (upstream and downstream) generated resulting from the choices made; (ii) the assessment of the most feasible alternative showing the best global environmental performance; (iii) return to scenario building if the achieved investigated alternatives do not highlights substantial improvements of the overall environmental performance.

The last step of this procedure (ex-post LCA) has not been performed in the present deliverable due to the large number of scenarios to be developed (four alternatives for each scenario, leading to a total of twelve different options), which requires the implementation of a remarkable number of LCA studies. Therefore, once built the EMA scenarios, it is advised the engagement of all the suitable actors to identify the solution of major concern.

2.1 – A Circular Economy framework

The Circular Economy (CE) framework is the common thread interlinking all the components of the developed procedure as a whole, leading to the construction of the delivered scenarios towards the most suitable environmental performance. CE becomes the next framework and business model, in which a breakthrough innovation is needed to address the shift from a linear production pattern (where waste and pollution are the rule) to complex networks (where waste from a process is the raw input to another process and emissions are minimized). The key issues addressed by this new model of production are:

- the concept of "zero waste";
- the necessity to implement the already existing activities;
- the employment and valorization of different available substrates (e.g. agricultural residues), suppliers and final users;
- the transition versus more sustainable input resources as well as intermediate recycling and output flows.

Such complex patterns also require complex and flexible technologies and comprehensive evaluation tools. Understanding and properly addressing network, substrates, technology and methodological complexities are therefore important goals to develop a theoretical integrated framework and operational model. The implementation of a circular economy, the appropriate resource management, the shift from providing services instead of products (e.g. good mobility instead of cars), the better image that such improvements provide, are likely to attract new companies and generate innovative businesses, thus generating a new set of jobs over the logistic chain, that replace old, no longer sustainable jobs, while also decreasing environmental impacts.

Circular model where products and materials continue to circulate seems to be the only solution to overcome the current consumption and production trends. According to Ellen MacArthur Foundation in the circular economy, products and materials should continue to circulate through maintenance, reuse and redistribution, refurbishment and remanufacturing, and finally recycling. The circular economy aims at keeping products, components and materials at their highest utility and value at all times preserving and enhancing natural capital, optimizing resource yields and minimizing system risks by managing finite stocks and renewable flows.

References

Goedkoop, M., Heijungs, R., Huijbregts, M., De Schryver, A., Struijs, J., van Zelm, R., 2013. A Life Cycle Impact Assessment Method Which Comprises Harmonised Category Indicators at the Midpoint and Endpoint Level; ReCiPe 2008. Dutch Ministry of Housing, Spatial Planning and Environment (VROM), The Hague, The Netherlands.

Ellen Macarthur Foundation, Towards the Circular Economy, (2012). https://www.ellenmacarthurfoundation.org/

Viglia, S., Civitillo, D.F., Cacciapuoti, G., Ulgiati, S., 2017. Indicators of environmental loading and sustainability of urban systems. An emergy-based environmental footprint. Ecol. Indic. https://doi.org/10.1016/J.ECOLIND.2017.03.060