European Futures for Energy Efficiency

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Executive summaries of revised deliverables

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Contents

WP2 deliverables: Macroeconomic ASA analyses of energy efficiency

D2.1 Energy efficiency trends and their drivers

Vehmas, Jarmo, Luukkanen, Jyrki, Kaivo-oja, Jari and Heino, Hanna

Executive summary

The task

The purpose of this deliverable is to find out how change in energy efficiency has affected energy use and related carbon dioxide (CO_2) emissions in the EU. This is done for CO_2 emissions by applying an extended Kaya identity which identifies the major drivers of CO_2 emissions. For energy use, a similar identity without CO_2 emissions is used:

$$TPES = \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP$$

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP$$

where TPES is total primary energy supply, FEC is final energy consumption, GDP is gross domestic product in real/constant prices, and POP is the amount of population.

These identities include major drivers related to energy efficiency: energy intensity (FEC/GDP) and the ratio between primary and final energy use (TPES/FEC). The first one is a proxy indicator of energy efficiency at the macro level, and the latter is a proxy describing the efficiency of the entire energy transformation system (the smaller the ratio, the better the efficiency).

Method

The effects of these and other drivers are calculated by using a chained two-factor incremental decomposition analysis developed in University of Turku, Finland Futures Research Centre.

Data

The data used in the analyses is collected from International Energy Agency (IEA) database, and it covers the years from 1990 to 2013. The collected data includes carbon dioxide emissions from fuel combustion (CO_2), total primary energy supply (TPES), final energy consumption (FEC), gross domestic product (GDP) in fixed (real) prices, and the amount of population (POP). The results are presented by summing up the annual decomposition results for periods 1990-2000, 2000-2005, 2005-2010 and 2010-2013 for each EU Member State and the EU-28 aggregate.

Results

According to the results, decreasing energy intensity (final energy consumption divided by gross domestic product, FEC/GDP) has had a decreasing effect to both energy use and CO_2 emissions in many EU-28 Member States during the whole period 1990-2013. During the shorter periods 2005-

2010 and 2010-2013, it has been a common practice and total primary energy supply and CO_2 emissions have decreased in most of the EU-28 Member States.

The ratio between total primary energy supply and final energy consumption (TPES/FEC) has not had such a clear effect. It has varied over time in most of the EU Member States, sometimes increasing and sometimes decreasing total primary energy use and CO_2 emissions. Even during the most recent years, no clear trend cannot be observed. However, increasing use of renewable energies (calculated as primary energy by multiplying the amount of produced electricity with a coefficient 1 in IEA statistics) should improve the ratio. If TPES/GDP is preferred as an indicator of energy intensity at the macro level, its contribution to the change of TPES and CO_2 emissions can be easily calculated by just summing up the effects of TPES/FEC and FEC/GDP.

Use of the results

The chained two-factor incremental decomposition analysis, developed and applied in this deliverable, is a flexible method for analysing country performance over time in relation to sustainable development. The analysis can be applied to also other entities than a national state. Actually, it can be applied to any entity at any level, if sufficient data describing the performance of the selected entity at the corresponding level is available. Selecting different indicators for analysis offers an opportunity to receive a wide perspective to an entity's performance − in terms of energy intensity, material intensity, and environmental intensity. Incremental analysis focusing on annual changes is advantageous, because results can be summed up to see development during any selected period between the first and last year of the time series. The method is useful for energy researchers, and the results, especially if updated by using more recent data, can provide important information about the effects of changing energy intensity to the policy makers and other stakeholders in the EU and the individual Member States.

D2.2. Synergies and trade-offs between energy efficiency and sustainability indicators: The EU-28 study of sustainable energy use

Kaivo-oja, Jari, Luukkanen, Jyrki and Vehmas, Jarmo

Executive summary

Task

The purpose of this deliverable is to analyse if similar or opposite developments can be found in the European Union Member States between energy-related and sustainability-related indicators and change in their values over time.

Method

This will be done by applying an empirical synergy/trade-off analysis, developed in University of Turku, Finland Futures Research Centre, for a set of energy-related indicators and other indicators. The energy-related indicators include gross inland consumption of energy, electricity consumption, energy intensity (Gross inland consumption/GDP), primary energy intensity, and carbon intensity of the economy (CO_2 emissions/GDP). The other indicators include two set of indicators. The first one includes three key indicators, namely value added, amount of population and amount of urban population. The second one includes the indicators used in the Sustainability Society Index (SSI). There are 21 different indicators describing seven different themes regarding sustainability, i.e. the basic needs, health, social development, natural resources, climate change, transition processes and the economy. There are a few individual indicators under each of these themes.

The empirical synergy/trade-off analysis is based on the ratio between relative changes over time in the observed values of each pair of analysed indicators. The relationship can be presented simply as follows:

$$Synergy = \frac{Smaller\ change}{Larger\ change}$$

The nature of the relationship is synergy, and it can get either positive or negative values between -1 and +1. For calculating the relationship, the self-values of the relative changes determine which one will be the numerator and which one the denominator. The relative change must be presented either in percentage calculated from the base year value, or a difference between indexed values of the base and target years. The base year can be a fixed (constant) one or a moving one. If it is fixed, we can speak about *stabilized synergy calculation*. If the base year is a moving one (e.g. annual or biannual changes), then we can speak about *dynamic synergy calculation*. The stabilized synergy analysis tells about the long-term synergy/trade-off trends, and the dynamic synergy analysis takes the annual or other shorter-term changes better into account. The latter analysis may e.g. reveal a possible cyclical nature of the relationship between changes in the analysed indicator pair.

Data

The data used in the analysis is taken from two data sources. The energy-related indicators and the three key indicators are analysed for the years 1985-2014, and the data is publicly available in the Eurostat database. The data for indicators of the Sustainable Society Index are analysed for the years 2006-2014, and the data is publicly available in the Sustainable Society Foundation website.

Results

In this report, stabilized synergy analysis is carried out for the EU-28 Member States using all pairs of the above mentioned energy-related indicators vs. the selected key indicators (value added, population and urban population) in the years 1985-2014, and using all pairs of energy intensity vs. the 21 Sustainable Society Index (SSI) indicators in the years 2006-2014. The dynamic analysis is carried out only for the indicators of the latter pairs, and the results are presented as an average of the annual results in the figures in Chapter 5. The annual results are not analysed, so conclusions about the possible cycles are not drawn. The annual results, are, however available in Annex 1 of this report.

Use of the results

The report includes a large set of empirical results, which are especially of academic interest. However, the results may give ideas also for policy makers and other stakeholder groups such as NGOs/citizens and energy industry/companies about interesting observations in relation to the synergies and trade-offs between energy-related and sustainability-related indicators.

D2.3 and D2.4. LINDA models: baseline and energy efficiency scenarios for the EU-28 Member States

Vehmas, Jarmo, Panula-Ontto, Juha and Luukkanen, Jyrki

Executive summary

Task

The purpose of this deliverable is to construct energy scenarios for the European Union and for individual Member States, and evaluate how the adopted energy efficiency related policy targets for the year 2030 could be achieved at the Community level. This is done by using the LINDA (Long Range Integrated Development Analysis) modeling approach developed in University of Turku, Finland Futures Research Centre.

Method

The LINDA modeling approach is based on data accounting and the model builds on the drivers of CO_2 emissions identified in an extended Kaya identity.

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP$$

where TPES is total primary energy supply, FEC is final energy consumption, GDP is gross domestic product in real/fixed prices, and POP is the amount of population. LINDA models are suitable for projecting the use of fuels and electricity, total primary energy use, and CO_2 emissions from fossil fuel combustion in different economic sectors. The projections, called also as LINDA scenarios, are results of the modeling. The different results are based on user-defined assumptions on:

- changing fuel mix in different sectors of the economy,
- expansion of economic activity in different economic sectors (as annual change rates of sectoral value added/share of GDP),
- annual changes in electricity and fuel use intensities (change rates per unit of generated value added/share of GDP),
- change in residential use of fuels and electricity,
- change in population growth, and
- changes in power plant capacity.

LINDA models the energy production side at high level, and the consumption side at relatively low level based on intensity trends. The LINDA models are well suitable for

- investigating how different schedules for transitions in fuel use and electricity production play out in terms of CO_2 emissions
- how different investment plans for power plant capacity will cover the electricity need of the system when different economic developments are assumed, and
- how different scenarios for energy efficiency will influence the use of fuels and electricity, and the need of new power plant capacity, as well as reaching CO_2 emission targets.

In the EUFORIE project, LINDA models have been constructed for 24 individual European countries, of which 21 are EU Member States, and for the EU aggregate covering all the 28 Member States. A LINDA model for China is also available. All the LINDA models constructed in the EUFORIE project and the user instructions can be downloaded from the project website, www.euforie-h2020.eu.The models are country-specific MS Excel files. A more detailed description of the model is included in this deliverable.

Data

The data used in the models is collected from various data sources, such as International Energy Agency (electricity, fuel, and CO_2 emission data), World Bank (economic data), United Nations (population data), EU DG ENER (power plant data), and ODYSSEE-MURE database (data of the transport sector).

Results

The results include different energy efficiency projections for the EU-28 as a whole, and for selected EU Member States (Finland, Germany, Italy and Spain). The baseline scenario for the EU-28 as a whole is based on historical trends of energy use and economic growth and on output of other modeling efforts resulting in the EU Reference Scenario 2016. This baseline scenario gives an answer to the question “Where will the expected/assumed energy efficiency trends lead the EU and its Member States by the year 2030?” Second, four different energy efficiency scenarios are derived from the baseline scenario by changing the input. The substance of these projections is to give different answers to the question “How the existing energy efficiency targets of the EU and its 28 Member States can be reached?” The table below presents the scenario results in relation to the EU targets. Finally, the baseline and energy efficiency scenarios are presented for selected EU Member States, i.e. for Finland, Germany, Italy, and Spain. For these Member States, additional industry-driven scenarios are presented for comparison. The 2030 targets for individual EU Member States are not available yet.

Summary of the LINDA EU-28 scenarios in terms of EU 2030 energy policy targets.

Indicator	**EU target 2030**	**LINDA EU-28 scenario**				
		Baseline 2030	*EFF1 2030 higher efficiency*	*EFF2 2030 lower efficiency*	*EFF3 2030 (EFF2 + commercial growth)*	*EFF4 2030 (EFF2 + industrial growth)*
Final energy consumption	-17 % from 2005	-12.1 %	-28.0 %	-20.9 %	-21.7 %	-16.0 %
Total primary energy supply	-23 % from 2005	-9.5 %	-25.5 %	-20,3 %	-20.9 %	-16.7 %
CO_2 emissions	-40 % from 1990	-35.9 %	-46.7 %	-44.0 %	-44.1 %	-42.2 %
Share of renewables	share 27 %	23.1 %	23.6 %	23.8 %	23.8 %	24.0 %

Based on these scenarios and their evaluation, major conclusion is that the renewable energy target is the most challenging among the energy-related policy targets adopted at the EU Community level for the year 2030. Targets of energy efficiency (primary and final energy consumption) and the CO_2 emission targets are less challenging at the Community level. However, differences between the individual Member States are large.

Use of the results

The LINDA models are valuable for all stakeholders interested in playing with energy scenarios and seeing how a change in the user-defined assumptions such as economic growth or energy intensity in different sectors of the economy, affects energy use and CO_2 emissions at the macro level. The LINDA modeling approach is useful in energy policy planning and scenario construction at the Community and Member State levels. The models are useful also for researchers who are willing to develop the model by adding more and more detailed information, and applying the LINDA modeling approach in other countries.

WP3 deliverables: Regional case studies of energy efficiency in Europe

D3.1. Analysis of the energy efficiency barriers at the regional level.

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Executive summary

Issues explored

An aware and effective resource-use policy making requires a deep, comprehensive and agreed upon assessment of energy systems as well as production and consumption processes. For this to happen, multicriteria and multimethod integrated approaches are needed and their validity must be tested at different spatial and time scales in order to develop reliable frameworks and indicators to serve as the starting point and monitoring tools of performances, costs & benefits and finally environmental and socio-economic sustainability. The operational features and results of such tools must provide a transparent and reliable basis for the involvement of all actors and stakeholders in the decision making process.

According to the EUFORIE Project scope and WP3 goals and tasks, this Deliverable D3.1 provides a large overview of systems and processes across scales, in order to generate case studies and a sufficient database in support of evaluation, scenario making and policy toolkit design towards effective resource use policies.

This deliverable is aimed at describing and understanding the limiting factors, bottlenecks and efficiency drops of energy demand. This goal was achieved providing insight into:

1. ***Understanding the interplay of material and energy efficiency***. Talking of energy efficiency is an incomplete exercise if not associated to material efficiency. In this deliverable several examples of processes - where energy, material and environmental benefits are coupled - were presented in order to assess the energy and material efficiency of metabolic patterns at different levels (process, activity sector, system).
2. ***Identifying the product or service provided by the process investigated, for easier comparison***: Well defined concept/functional units were referred to for each investigated case or aspect where policy decisions are needed. In so doing comparison becomes possible and processes can be improved or placed in the appropriate context.
3. *A**ppropriate monitoring and assessment methods and performance indicators.*** Answers to the following questions were provided: “efficiency to do what?”, “efficiency at what scale?”, “efficiency for how long?”, “efficiency to whom?", about the goals, the spatial and time scales and the final beneficiaries of the achieved or pursued material and energy efficiency.
4. ***Overcoming mono-dimensional energy assessments*****.** They prove not to be very telling in the presence of complex systems and multi-input/multi-output processes. Trade-offs are the most frequent case, where achieving an improvement of energy efficiency may require to decrease the material or the environmental or the sustainability performance of the system.

5. ***Synergic integration*** of different (and more comprehensive than just energy) assessment methods was achieved. This allows a deeper understanding of the premises of each method and efforts to integrate some of them into an organized and consistent assessment procedure. One size does not fit all.
6. ***Transparency in performance assessment*** becomes the basis for discussion, understanding and quality improvement (Aarhus Convention, 1998). Stakeholders need a complete set of data, links and scenarios, in order to be able to reach the above referred to "governance-by-disclosure". Most often discussion, dialogue, participatory governance, and appropriate problem-solving processes are prevented by lack of suitable information, so that decision-making processes translate into "talking of nothing".

Investigation performed

- ***Understanding the role played by energy demand and energy quality***, when possible also coupled to material demand. Identifying the present energy efficiency and the phases where efficiency drops occur.
- ***Identifying a set of potential solutions for energy efficiency improvement.*** Identifying environmental, material and energy costs and benefits, constraints and barriers to the implementation of such solution.
- ***Assessing the potential of larger scale and EU scale implementation of proposed solutions,*** through geographical exploration of needs, potentials and constraints as well as scenario making over time.
- ***Exploring the integration of the different approaches*** into a procedure for policy making.

The Work Package activities have focused on different aspects that can be summarized as follows:

- **Energy efficiency**: how energy efficiency concepts emerge within a specific case study, process, system.
- **Material efficiency**: how appropriate material use and recycling affect energy demand.
- **Quality assessment versus efficiency**. Replacement of input and output flows makes the system different and may generate burden shifts or affect the functional unit.

Method(s) employed

All Methods are described in the present Deliverable D3.1. The WP was mainly carried out by integrating Life Cycle Assessment (LCA), Cumulative Energy demand (CED) and Emergy Accounting (EMA) approaches. Partial integration was also achieved with MuSIASEM and ASA approaches. Papers illustrating case studies and results are included in the Deliverable D3.1, full version, as well as in the Appendix of Deliverable 3.2, full version.

Data and sources

The large amount of data needed for the case studies come from very different sources. Some of these data are primary, in that they have been personally collected from the team members by means of direct contacts with the actors (operators, companies, managers, administrators) involved in each case. Also secondary data (statistical Yearbook, databases, governmental reports, business and environmental organizations) have been collected and processed. In few cases, tertiary data were also used (from modelling exercises, estimates, assumptions and educated guesses).

Data collection and performance indicators provide a transparent description of the investigated cases and, more than that, show that this can be done in a way that can be managed by interested stakeholders. This way to achieve an environmental governance emphasizes a trustworthy relationship between civil society and governments and increases participation to the decision making process, in so promoting a so-called "governance-by-disclosure" (Aarti, 2008[1]).

Results

A large number of case studies are addressed. In each case study one or more investigation approaches are applied and their integration is pursued. The results are multi-fold:

1. *to show that a system or process can be investigated with focus on material and energy efficiency, based on quantitative data*, instead of only relying on a qualitative description;
2. *to provide a set of performance indicators*, to show different aspects of the process/system and to move beyond mono-dimensional descriptions. Indicators can be used to show trends and compare performances.
3. *to show that results from one approach can be usefully transferred to another approach in order to achieve more comprehensive and synergic understanding*. In so doing, much more can be extracted out of the same set of primary, secondary and tertiary data.

The addressed case studies are available in the 13 Chapters of Deliverable D3.1. Most of them were published as papers in international Journals, where appropriate reference to the EUFORIE Project is provided. The list of such papers is also included in Deliverable D3.1.

Significance for policy-makers, stakeholders and other researchers. The added value of approach integration.

Take-home message:

Transparent policy making requires decisions be based on data/indicators/scenarios available to everybody. Procedures and toolkits to generate performance indicators, impacts and scenarios must be designed and implemented in a way that stakeholders can understand them and benefit. Mono-dimensional indicators are unlikely to provide sufficient understanding and suitable basis for discussion, decisions and conflict prevention. It is possible to design and implement calculation procedures and toolkits that convert data into indicators and then potential choices, to promote participatory strategies and roadmaps.

We designed such a procedure mainly based on the integration of LCA and EMA, with few cases also including other approaches (SUMMA, MuSIASEM, ASA). All of these approaches share many similarities in the way they are applied: they start from model definition, are based on the same data inventory, and provide indicators that may help choices and improvement. Therefore, the inclusion of all of them in the designed procedure can be easily implemented later on.

In the present design, mainly limited to LCA and EMA approaches for the sake of simplicity, LCA indicators are divided into two categories, respectively focused on resources used (‘upstream’ impact) and on the system's emissions (‘downstream’ impact), while EMA indicators, being focused on the

[1] Aarti, Gupta (2008). "Transparency under scrutiny: Information disclosure in Global Environmental Governance". *Global Environmental Politics*. **8** (2): 1–7. doi:10.1162/glep.2008.8.2.1

environmental support to and performance of a process on the global scale, are proposed as an upstream complement of LCA indicators. The emergy accounting is extended back in time to include the environmental work needed for resource formation. When the two methods (LCA and EMA) are integrated and jointly applied, the following added values are achieved:

1. **Consistency of results:** the same set of data is used for both approaches;
2. **Comprehensiveness of investigated aspects**: by adding a number of input flows (environmental, labor and services) that are not included in LCA the assessment does not limit to conventional resources (fossil fuels and materials), but acknowledges the importance of other resource categories, sometimes not even included in market economy evaluations;
3. **Expanded focus:** A clear picture of the process is provided by indicators of performance and sustainability that refer to different "questions" and scales.

Figure 1 shows the sequence, feedbacks and iterative links among the different approaches: from raw data inventory, through processing via SUMMA, LCA and EMA (performance assessment) and MuSIASEM (economic, population and scale constraints) to Modelling and scenario making (via ASA, LINDA, Decomposition analysis and socio-economic assessments), are shown. Each step provides data and performance indicators to the downstream one, which in turn generates feedbacks to the upstream steps for refocusing and better monitoring.

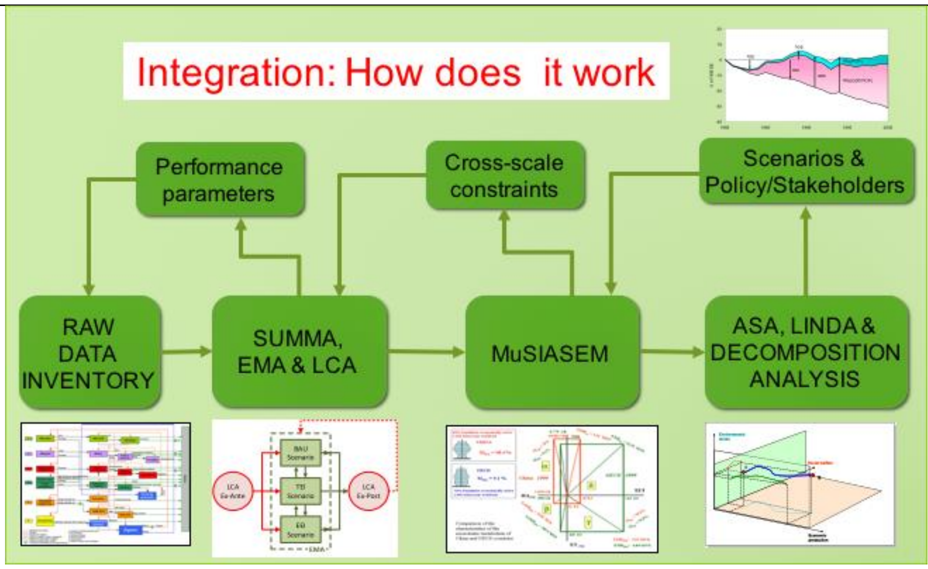

Figure 1. Integration patterns among the different approaches applied within the EUFORIE project. Schemes illustrating each step are from papers or Deliverables published during the project.

The sequential diagram in Figure 1 offers an overview of the assessment procedure, for user friendly policy-making and stakeholders involvement according to a participatory roadmap (Vassillo et al., 2019). (Figure 2)

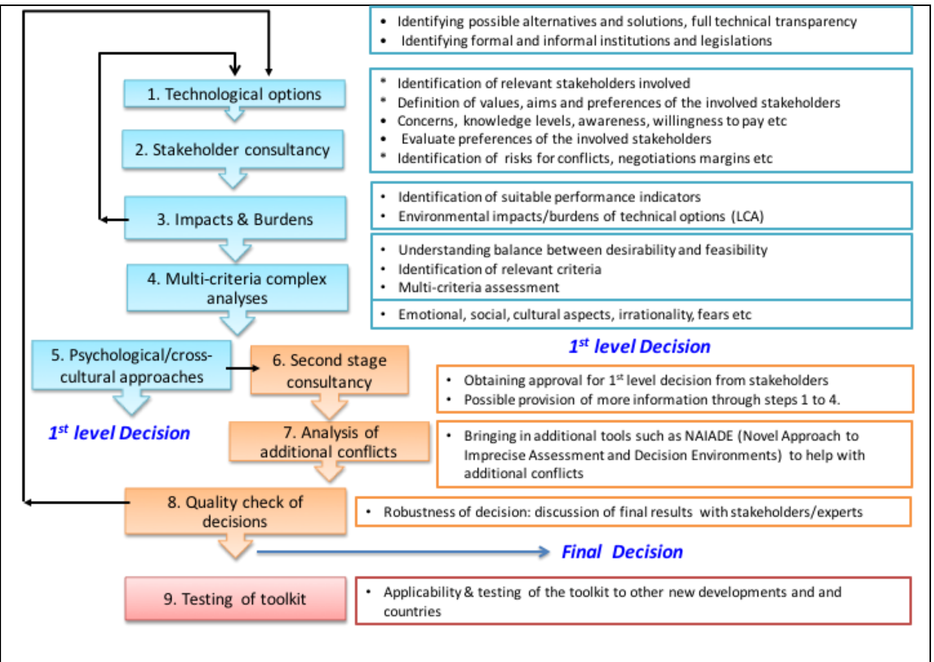

Figure 2.
A participatory roadmap for conflict prevention and shared strategies towards appropriate resource use and policy making.
(Vassillo et al., 2019)

D3.2. Report on costs of solutions, initial findings and work in progress

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Executive summary

Issues explored

1. Maximizing energy efficiency is not always the best strategy, in that processes are not only driven by energy.
2. Other resources are crucial, such as water and materials (e.g. rare earths, to quote some), which calls for simultaneous appropriate use of a set of input resources, including energy.
3. At the same time, minimization of impacts, which are not linearly linked to energy consumption, is also a key strategy.
4. Efficiency maximization (instead of appropriate use of resources) most often increases process time, in so decreasing power output.
5. Resources and energy flows to be characterized by their amounts, environmental quality and renewability. These factors affect the quality and the yield of the process and call for a deeper and more comprehensive understanding of the interplay of input and output flows.
6. Optimization versus maximization strategies, by appropriate tuning of input resources, output flows (yield, co-products, emissions) and time.
7. To design an assessment tool that applies a selection of evaluation approaches and allows a comprehensive assessment of key environmental and resource issues in a process. Such a tool may support collaborative and participatory interaction among stakeholders and policy makers, conflict prevention, and appropriate environmental management.

This deliverable provides increased understanding of three main aspects:

- the extended meaning of the concept of "cost": non only economic cost, but also resource and environmental cost;
- the need for a performance optimization strategy rather than an efficiency maximization strategy;
- possibility to design a tool in support of participatory strategies. The tool would ease the evaluation of alternative options and would generate scenarios, in support of policy making.

Investigation performed

Our point is that not only energy efficiency is crucial to the full understanding of a process or system's dynamics, but also other categories of driving forces, including ecosystem services, material flows, monetary flows. Optimization, not maximization, of resource use compared to the achieved or intended yield should the final goal of economic and environmental policy.

The goals of this Deliverable

The goal is to provide the basis for transparent discussion that goes beyond mono-dimensional choices (e.g. maximizing energy efficiency) and embraces a comprehensive set of consequences (resource depletion, environmental impacts, societal impacts and constraints such as land use, jobs, salaries) investigated thanks to the synergic application of selected environmental assessment tools (LCA, GIS, EMA, MFA), each one characterized by appropriate scale, objective and design. The proposed tool, preliminarily designed by merging LCA and EMA, may undergo further integration with other approaches within the EUFORIE project (MuSIASEM, ASA, LINDA, etc), to provide full understanding of the options at stake, as well as performance drops and improvement potential.

The contents of this Deliverable

We stress the "optimization versus maximization" aspect and suggest the possibility to design a tool for performance assessment of processes, to be used by policy makers and stakeholders to understand costs & benefits associated to different alternatives. The tool will not be developed in its full, user-friendly version, in that its implementation would require informatics skills that are outside the expertise of the Consortium members. The research will focus of the rationale, requisites, structure and perspectives of an "efficiency and optimization" calculator, which would require a dedicated project to become an effective policy-making and stakeholder participatory tool. The expected result is to generate a support framework (what are the constraints, what is important, goal and scope) and basis (where to start, how to measure, who is in charge for) for participatory strategies and collaborative interaction among policy makers and stakeholders.

Method(s) employed

All methods are explained in details within Deliverable D3.1 Section 3. Therefore, we skip this explanation and move directly to clarify the major features of the proposed tool. In particular:

- **Energy and material efficiency: how efficiency concepts emerge within a specific case study, process, system.** Focus was paid on flows carrying more energy or valuable matter (how can these inflows be decreased via process design improvement, distance from flow source, flow replacement, etc), on resource demanding process steps (how can they be modified via process design, distance and transport issues, machinery replacement, removal of redundant or useless steps or merging with other steps), and finally identification of still usable waste flows (e.g. residual heat), of cogeneration potential (development of new co-products) and options to decrease waste flows (i.e.: feedback flows, cascade design).
- **Quality Assessment versus efficiency.** Replacement of input and output flows changes the system and may generate burden shifts or affect the functional unit. Focus was paid on the environmental quality of resources (biosphere work to generate them, renewability), costs and benefits of their replacement with other resources, suitability and benefit of a given resource use in a process, extraction of valuable products from apparently useless materials (e.g. platform chemicals from biomass), integration and continuous monitoring of energy, material and environmental indicators in order to check trade-offs between higher efficiency and unexpected burden shift affecting the quality of the surrounding environment. Actually, quantifying the trend of environmental indicators versus improvements of energy efficiency might provide a measure of the “marginal cost” of improving energy efficiency.

Data and sources

Deliverable D3.1 was the starting point of the present deliverable, in that the availability of a large number of case studies at different space and time scales allows all kind of tests for inflow replacement, sensitivity analysis, process redesign, process integration, circular patterns.

Results

1. A prototype tool for optimization of costs and benefits (resource use and impacts versus yield)

The goal of the present "efficiency versus power output" research is to design a tool that can be used to make estimates and scenarios. Such a tool might be a valuable contribution to policy making, as far as resource use and impacts of processes are concerned. In fact, energy and resource efficiency as well as minimization of airborne, waterborne and solid emissions are among the most urgent policy issues of national EU governments and the EU Commission. The tool allows to identify input and output flows, to attribute them appropriate quality and characterization factors typical of the selected assessment approaches and finally to calculate performance indicators of processes and policies across scales.

2. The structure of the proposed assessment tool

The structure of the proposed tool (rationale + inventory + calculation procedure + performance indicators + diagrams and scenarios + alternative policies) is preliminarily shown in Figure 2.

The proposed prototype tool must be endowed with:

a) a user-friendly input page;
b) a transparent calculation procedure, including characterization factors, footnotes, references;
c) an output page with calculated performance indicators and diagrams;
d) a structure of the calculation procedure that allows sensitivity and/or uncertainty estimates (i.e. the possibility to modify the input data or the characterization factors by a desired percent in order to ascertain how changes on input values affect results). This is the core of the calculation procedure, to understand to what extent changes in the amount of input flows affect the output (in so addressing the alternative "optimization versus maximization").
e) the possibility to add comparisons over time and/or generate standardized comparison with a reference year or a reference system. Without such standardization, expected, planned or achieved improvements cannot be assessed.
f) a sufficient flexibility to allow further integration and comparison with data from other approaches.

Selected data about an agricultural system and an urban system are presented and discussed in the last pages of the Deliverable D3.2, for the sake of clarification and preliminary example.

Discussion: Significance for policy-makers, stakeholders and other researchers.

Integration with other approaches.

The magic bullet, as well known, does not exist. What we have experienced within other projects as well as within the present project EUFORIE - also thanks to the interaction with stakeholders - is that one approach only cannot ensure full understanding of costs and benefits. As a consequence, results from whatever approach must be compared to results from other assessment tools characterized by different assumptions, frameworks and design. Other approaches will be indicated and explored for integration (e.g.: MuSIASEM and others in the present EUFORIE project, Ecological Footprint, Carbon Footprint). The prototype tool we are designing will also clarify constraints, strengths and weaknesses of achieved results and will also indicate their realm of reliability, so that users are informed of what can be expected from it. (Figure 1)

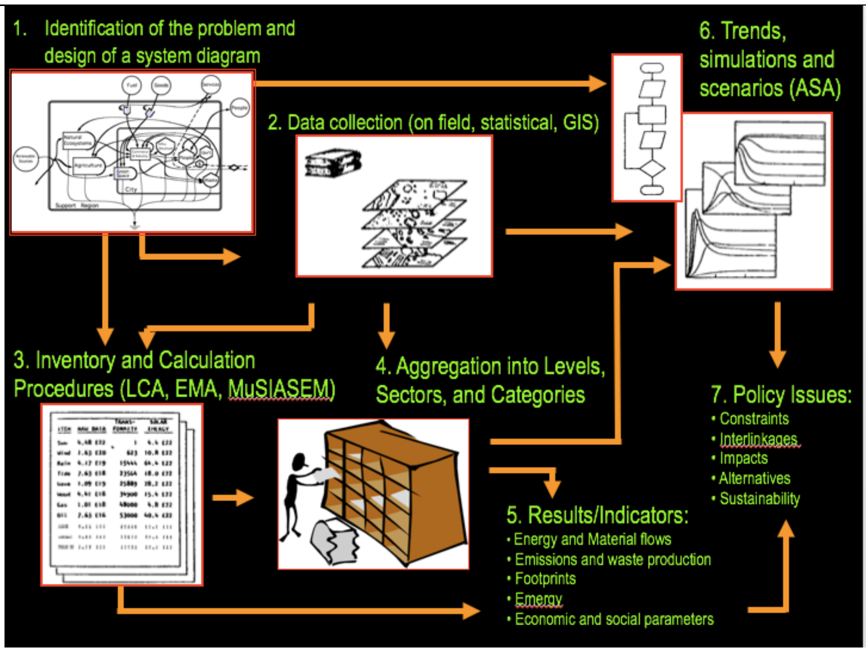


Figure 1. Preliminary schematization of the proposed calculation tool for policy making and participatory discussio**n**

Maximization versus optimization

According to irreversible thermodynamics (Prigogine, Onsager) and ecology concepts (Odum E.P. and Odum H.T.), natural systems do not proceed towards maximization of one or few specific characteristics of a system, but instead aim at achieving the maximum stability and sustainability (and evolutionary competitivity) by providing advantages to all components and levels of a system's hierarchy. According to the so-called Lotka's Maximum Power Principle and then redefined as Lotka-Odum's Maximum Empower Principle, maximum outcome of a system's activity is never ensured by the highest possible efficiency.

This is due to the fact that maximizing the use efficiency of only one resource inflow or the efficiency of only one process within the myriads of processes that compose an ecosystem or an economy, increases the misuse of large amounts of resources and requires more process time, thus decreasing the actual power output (product delivered per unit time). This is not the way natural selection and evolution proceed.

Maximizing the efficiency is possible, but it is not the best strategy to maximize the global output, i.e. production and growth, or, which is the same, **maximizing power output - which is the strategy of sustainable ecological systems - does not necessarily require maximizing efficiency,** but depends on the specific situation a system is facing in relation to the available resources. Some suggest that this is, for example, the case of circular economy, with resource exchanges and recycling.

D3.3.Assessment of costs and benefits of energy efficiency solutions

Ulgiati S., Franzese P.P., Fiorentino G., Zucaro A., Rallo R.F., Corcelli F., Casazza M., Santagata R., Giampietro M., Pérez-Sánchez L. and Velasco-Fernández R.

Executive summary

Issues explored

Within the previous research activity of the EUFORIE project we stressed the relations between material and energy efficiency as well as aspects of optimization versus maximization of performance parameters, in agreement with Lotka-Odum's Maximum Power Principle, by addressing in particular:

- the extended meaning of the concept of "cost": not only economic cost, but also resource and environmental costs, to be minimized;
- the need for a performance optimization strategy (benefits under multiple points of view and for multiple beneficiaries) rather than an efficiency maximization strategy (increase of benefits under one point of view or for one beneficiary only);
- the possibility to design a tool in support of participatory strategies (involvement of stakeholders in all steps of the decision making process). The tool would ease the evaluation of alternative options and would generate scenarios, in support to policy making.

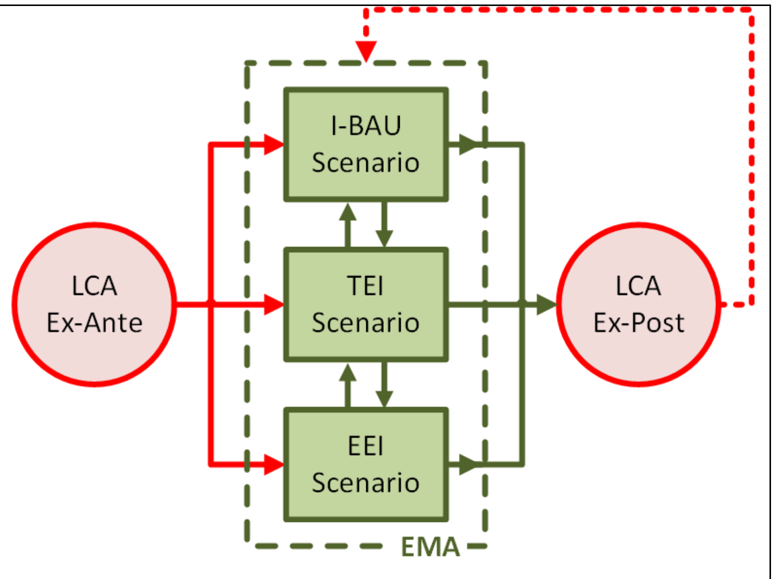
Concerning the latter point, "tool design" does not mean to deliver a fully operating software version of the desired evaluation tool, but instead identifying the criteria, the procedures and the operative features of a tool capable to assess actual performances and generate efficiency improvement scenarios. This would allow the future implementation of a suitable software for such a tool, with the help of programming experts, if supported by adequate sources of funding. As a consequence, in Deliverables D3.3. and D3.4 the term "tool" refers to the sequence "framework + rationale + diagram + calculation procedures + selected approach integration roadmap" which can be the basis for a future fully operative, user friendly online calculator.

In the present Report we focus on three of the case studies previously described in D3.1 (and published in refereed Journals), as representative of process, sector and system levels, in order to describe and clarify the suggested rationale and procedure and to show how it can be implemented in a policy tool. The case studies representative of the three levels (process, sector and system) were selected among the ones available in the set of cases investigated and described in our first Report within the framework of the EUFORIE project. For the sake of clarity, process level case study relates to electricity production (from grid and innovative sources), sector level relates to recovery and recycling of WEEE (informatics and PV devices), system level relates to the performence of an urban system receiving inflows from the lower levels. *The goal is not the case as such, but instead to show how each case is addressed, in order to understand to what extent it contributes to the final performance of the system for which a policy strategy is searched.*

Investigation performed

The process, sector, system levels above mentioned may be designed and implemented in different, more or less innovative and efficient ways. The designed procedure aims at ascertain the consequences of each choice, for informed policy. *A preliminary ex-ante LCA allows to identify the input flows responsible of the largest impacts in the Average Business-as-Usual perspective (A-BAU) before improvements are applied. Improvement patterns are: 1. Improved Business-as-Usual (I-BAU),* *with assessment based on results from already available best practices; 2. Technological Efficiency Improvement (TEI), based on a purposefully applied innovative technology; and finally, 3. Eco-Efficiency Improvement (EEI), based on the replacement of a resource by means of a more environmentally friendly one, according to the emergy approach. These scenarios are therefore characterized by different inventories. Ex-post LCAs would allow to ascertain to what extent the proposed changes contribute to address and solve the identified efficiency and environmental problems, by also providing feedback suggestions* (Figure 1).

Figure 1.
Diagram of the proposed assessment procedure. Problems identified by the ex-ante LCA are addressed by means of different solution strategies the resource performance of which is evaluated by means of the EMA approach. Finally, an ex-post LCA is used to assess which strategy has been able to minimize or solve the problem(s) and suggest a choice.



After applying the Figure 1 procedure to the process level (for its local improvement and decision-making), same is done with the sector level (i.e., in this Report, the production of photovoltaic electricity PV and end-of-life recovery of waste electric and electronic equipment, WEEE) as well as the system level (urban or regional economy). While the identification of the more impacting flows is performed via LCA in all the levels, the scenarios for each level are investigated via the emergy accounting method and indicators, capable to provide a very comprehensive environmental picture of the investigated case. Each LCA assessment includes a user interface (to be adjusted in a suitable way when the final tool is created). A simulation program is applied to each level procedure in order to understand how and how much the assumed input flow changes affect the performance indicators, in a kind of sensitivity procedure. In the final tool, the changes will apply to all the input flows, while in this Report oscillations only apply to one or two selected inflows.

Method(s) employed

All methods are explained in details within Deliverable D3.1 Section 3. Therefore, we skip this explanation suggesting the interested reader to make reference to D3.1. Within the research activity related to Deliverable D3.3, the MuSIASEM approach was applied to the urban systems of Napoli, Barcelona and Hongkong. The related published papers are provided as an Appendix of D3.3 together with a paper about the SUMMA approach method and selected results.

Data and sources

Deliverable D3.1 was the starting point of the calculations carried out in the present deliverable, in that the availability of a large number of case studies at different space and time scales allows all kind of tests for inflow replacement, sensitivity analysis, process redesign, process integration, circular patterns.

Results

According to the project proposal, three different levels were investigated in the same geographical framework in a way that the process and sector level could be consistently integrated within the system level. The case studies were selected from deliverable D3.1, as above mentioned. In particular, the animal by-products case study was investigated at process level, the photovoltaic electricity and end of life case study at sector level and the Naples urban case study at system level. In Figure 2 the interconnections among electricity production from animal waste, recovery of WEEE (Waste Electric and Electronic Equipment, e.g. photovoltaic panels, computers) and urban system are highlighted within a circular economy perspective: the savings in the production of electricity compared to the conventional route as well as the energy savings linked to the recovery of materials from WEEE translate into a better sustainability performance of the whole urban system.

The development of the prototype 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 14040, 2006; ISO 14044, 2006; EC, 2010; EC, 2011). EMA integrates renewable sources, resource generation time, trade flows, resource quality aspects, labor and services in the LCA approach.

The intended goal is to design and make available a tool for discussion of policies, building on partial tools that we have already created for energy systems (fuel cells) and water-energy-food nexus at urban level. If the final version of the tool becomes available (perhaps in a following EU funded project, taking advantage of informatics experts), it may be used by policy makers and stakeholders to quickly identify the performance changes generated by technological or environmental choices or simply by more accurate use of resources, capable to affect material and energy efficiency.

The goal of the developed tool is to identify hotspots and consequences of choices and propose potential energy and material efficiency improvement patterns as policy actions. A user interface with inputs and corresponding variability percentages (uncertainty) was designed and linked to the LCA and EMA calculation procedure worksheets in order to identify the main input flows affecting the environmental performance of the investigated scenario and to implement the above-mentioned improvements for the hotspots. The tool, by means of a macro coded in VBA (Visual Basic for Application language), will compute 200 random values for each scenario choice, updating the various indicators and plotting them into graphs.

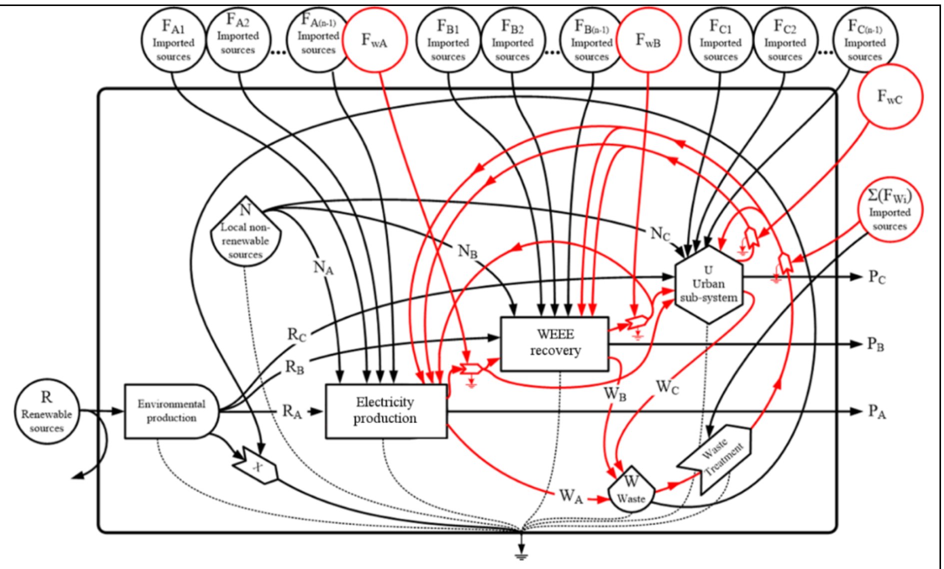


Figure 2. System diagram of the integrated circular urban system. It shows the interconnections between the different levels presented in a circular framework.

Discussion: Significance for policy-makers, stakeholders and other researchers

First take-home message:

It is very important to point out that a tool capable to generate quantitative performance indicators based on choices on the input side allows the discussion of policies based on facts instead of words, quantitative measures instead of ideological bias, possibility to choose intermediate or optimum solutions that take into account at least partially the requests of all stakeholders. This is impossible when there are no quantitative measures and scenarios on the discussion table.

The analysis performed by applying the EUFORIE prototype tool showed a better environmental performance within the Eco-Efficiency Implementation (EEI) scenario due to the improvement obtained thanks to the partial substitution of mainly fossil energy sources with renewable ones (in principle, substitution of sources characterized by high UEV with sources characterized by lower UEV, namely lower environmental cost). A further improvement could be obtained through the complete substitution of the nonrenewable energy sources. Moreover, simultaneous application of TEI and EEI strategies could lead to the implementation of very environmentally sound policies.

Second take-home message:

The main findings from the test-application of the calculation procedure to the three scenarios analyzed:

- The crucial importance to carefully monitor the local and cumulative energy and resource use by cities as well as to realize that energy demand grows nonlinearly with urban systems' size;
- The use of locally available resources (use of renewable energy and recycled materials) could generate positive consequences at local and global scales;
- Overcoming mono-dimensional assessments (only assessing energy or specific material flows) would push policy-makers towards the possibility to deeper investigate a network of flows, merging different methods and suggesting effective and comprehensive sustainability policies.

Third take-home message:

Understanding which flows are the top contributors of the demand for environmental support in each scenario helps identify the strength or fragility, the sustainability and the resilience of the investigated system, according to the dependence on specific local or imported, renewable or nonrenewable resource flows, and becomes the basis for more suitable resource policies.

D3.4. Standardization and integration of assessment methods focused on energy efficiency

Ulgiati S., Franzese P.P., Zucaro A., Fiorentino G., Santagata R., Corcelli F., Rallo R.F., Casazza M.

Executive summary

Issues explored

The aim of deliverable D3.4 is to reach a final design of a calculation procedure aimed to support stakeholders and policy makers when dealing with discussion and decision processes about environmental sustainability issues. This EUFORIE Calculator 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 goal of 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. To illustrate how the EUFORIE Calculator works for the assessment of the environmental issues, a case study representative of the system level (Napoli urban system) was selected and developed.

Investigation performed

The procedure starts with a preliminary Life Cycle Assessment analysis (ex-ante LCA) of the system as it is (Average Business-As-Usual, A-BAU), 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 as Improved Business-As-Usual (I-BAU), Technology-based Efficiency Improvement (TEI), Eco-Efficiency Implementation (EEI) 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 Improved Business-as-Usual, Technological and eco-Efficiency Solution Scenarios ==> ex-post LCA ==> assessment of achieved solution.

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, and
3. an assessment of the final performance of the system under study, as a consequence of the solution implementation.

A general assumption is made about the output generated: we assume that the same product can be obtained either in case of careful management (I-BAU), innovative technology (TEI), and increasing quality of selected inflows (EEI). In order to compare on the same basis the results of the three scenarios, calculated emergy performance indicators (total U and UEVs) are compared. Of course, a likewise comparison would be impossible if - for example - the 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 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)**, 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). Compared to ordinary BAU, the I-BAU scenario can be defined as "wise and careful management". 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%.

Method(s) employed

EMA and LCA methods are explained in details within Deliverable D3.1, Section 3. Therefore, we skip this explanation and move directly to clarify the major features of the proposed tool.

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.

The Tool is composed with:

1. an ex-ante LCA analysis to identify the main hotspots;
2. 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

3. summary sheet, where variation charts are reported;
4. 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;
5. 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.

How it works

By means of an ex-ante LCA performed on the system as it is, without any improvement action (Average Business-as-Usual, A-BAU) the most impacting impact categories are identified. Solutions aimed at decreasing these impacts are suggested according to the three scenarios I-BAU, TEI and EEI, generally limiting to only one (the largest) input flow (or more if needed). For the sake of clarity, if the ex-ante LCA suggests that the electricity input is the most crucial flow in terms of impacts generated, its amount can be decreased by applying wise management practices or good care of the process (I-BAU), can also be decreased by implementing innovative technological solutions (e.g. LED - Light Emission Diodes instead of incandescent light bulbs), or impacts can be decreased by replacing the grid electric input (national mix) through less impacting sources (e.g. Photovoltaic). The three scenarios give rise to 3 or more new inventories, depending on the number of solutions implemented especially in TEI and EEI scenarios. Based on these new inventories, new ex-post LCAs can be performed, in order to ascertain if the proposed solutions have solved the impact problems identified in the ex-ante LCA. If one of the scenarios solves the problem, then stakeholders and administrators will have to decide if this is acceptable for them (the scenario that solves the problem might in principle be the one that has the lowest EMA cost or the higher EMA cost, which calls for policy decisions by interested actors.

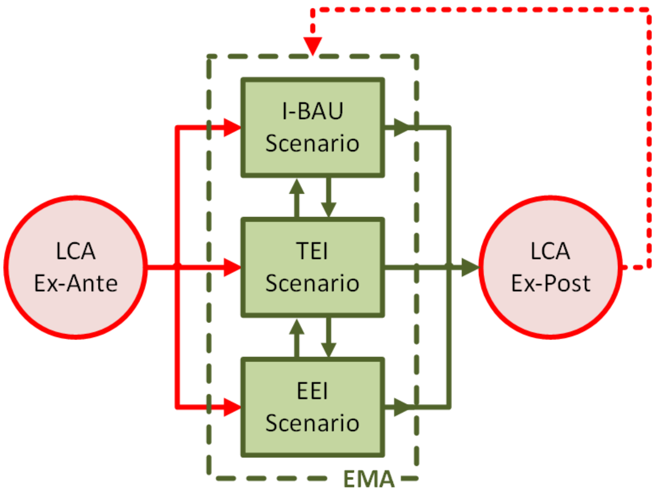


Figure 1. EUFORIE Prototype Tool Framework.

Data and sources

Data from case studies of Deliverable 3.1 are used for ex-ante and ex-post LCAs as well as for I-BAU, TEI and EEI scenarios implemented.

Results

The prototype tool was applied to the urban system of Napoli, limiting the analysis to electricity, natural gas and Iron&Steel inflows, after having verified their crucial role in generating emissions, by means of an ex-ante LCA (see Deliverable D3.4, full version). The analysis concerned the process levels (specific cases of electricity generation, natural gas extraction and refining, iron and steel extraction and manufacturing into technical equipment), the sector level (assumptions about implementation of technological innovation in the considered activities), the final system's level (provision of resources to the urban system, by also taking into account energy and matter recycling processes or replacement of material and energy sources). In all levels, I-BAU, TEI and EEI options were considered (as described above, Section 2). Scenarios were evaluated by using the EMA approach, which provides results with and without Labor and Services (L&S). Labor and Services (namely the know-how provided and the infrastructure surrounding and supporting the system) also have an emergy cost, that should not be disregarded. However, it may be very useful to compare results with and without the inclusion of L&S.

The Figure 2 shows the I-BAU scenario, with and without L&S, for the performance of the urban system. The value provided on the vertical axis is the total emergy use per year by the city, if electricity, natural gas and iron&steel are managed by means of the best management practices currently available. The other inflows are also quantified in emergy terms and added to the total, but their management is not considered as accurate. Results (red line, average of all uncertainty oscillations occurring) show a value around 1.905 E+22 sej/yr with L&S and a much lower 8.718 E+21 sej/yr without L&S.

Similar simulations are also shown in Figures 3 and 4, for TEI and EEI scenarios. The I-BAU scenario shows higher emergy costs than the TEI scenario, which in turn has higher costs than the EEI scenario. All values with L&S are much higher than without.

Variation between -10% and +10% of selected hot-spots

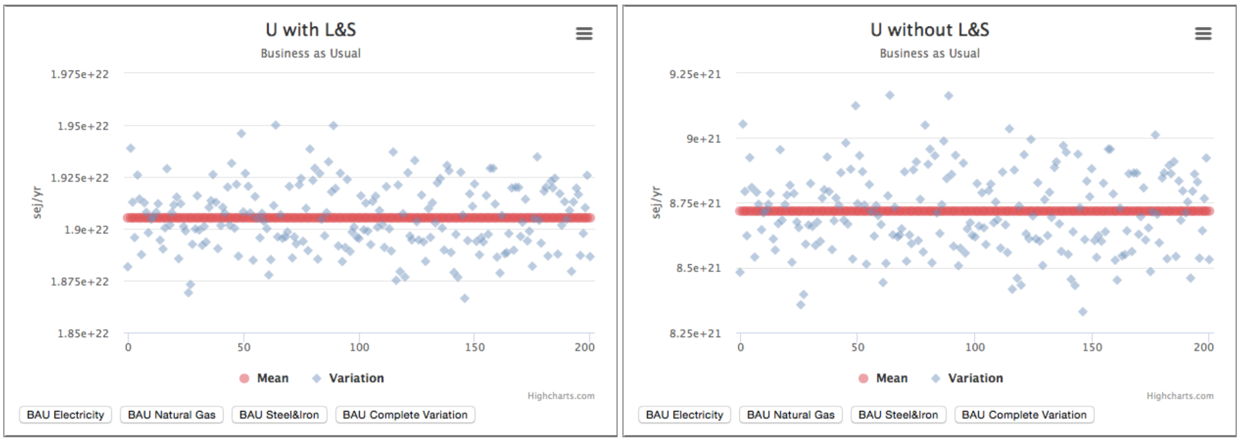


Figure 2. I-BAU scenario of urban system, with and without L&S. Results (red line, average of all oscillations occurring) show a value around 1.905 E+22 sej/yr with L&S and a much lower 8.718 E+21 sej/yr without L&S.

Variation between -20% and 0% of selected hot-spots, resulting from a more efficient use of resources

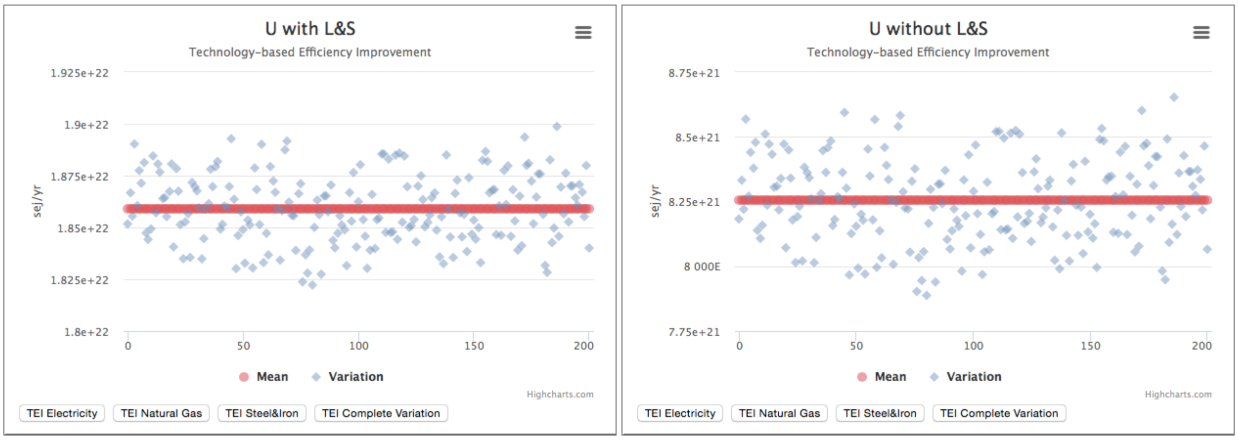


Figure 3. TEI scenario of urban system, with and without L&S. Results (red line, average of all oscillations occurring) show a value around 1.859 E+22 sej/yr with L&S and a much lower 8.255 E+21 sej/yr without L&S.

Variation between -10% and -5% of selected hot-spots

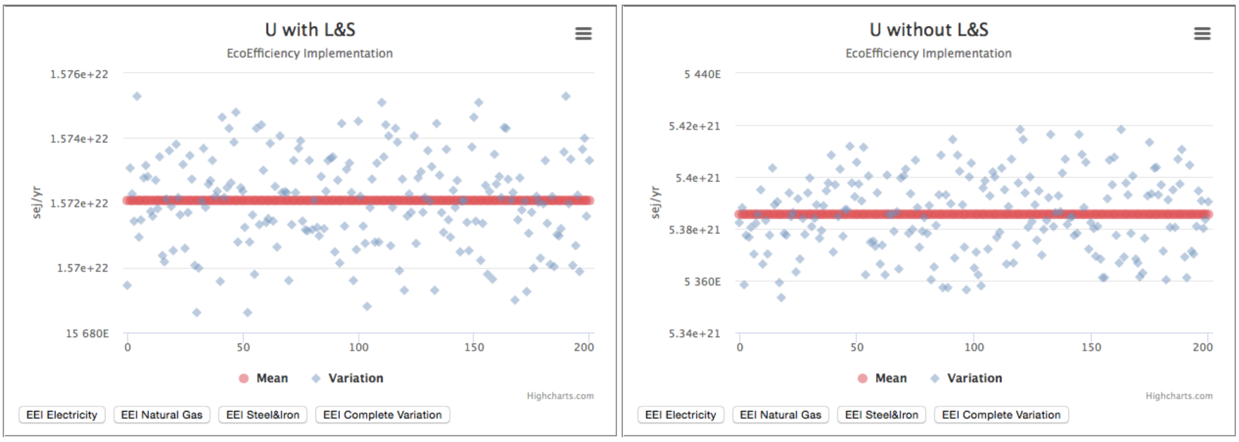


Figure 4. EEI scenario of urban system, with and without L&S. Results (red line, average of all oscillations occurring) show a value around 1.572 E+22 sej/yr with L&S and a much lower 5.385 E+21 sej/yr without L&S.

Results given in Figures 2, 3 and 4 are generated by assuming the simultaneous provision of electricity, natural gas and ferrous metals to the urban system according to the features of I-BAU, TEI and EEI scenarios. As said above, these crucial resource inflows can also be tested separately.

Figures 5, 6 and 7 provide the resulting total emergy use by the city of Napoli within the scenario EEI, in case only electricity (Figure 5), natural gas (Figure 6) or iron&steel (Figure 7) are respectively managed according to the EEI definitions. It clearly appears that total emergy use is higher than for Figure 4 (indicating higher demand from traditional sources). In a like manner, other inflows can be managed according to resource saving options (efficiency) and resource quality (eco-efficiency), in so generating much higher improvements for the urban system. The ex-post LCA, concerned with the impact category Global Warming Potential highlighted by the ex-ante LCA, shows that the EEI scenario provides a marked decrease of the GWP value, in so suggesting a solution that is also environmentally friendly (lower demand of indirect environmental support as well as for direct ecosystem services).

Figure 5.
EEI scenario of urban system, without L&S, in case only electricity is managed according to EEI requisites (in this case, from slaughtery waste and photovoltaic source). Result (red line, average of all oscillations occurring) shows a value around 7.280 E+21 sej/yr.

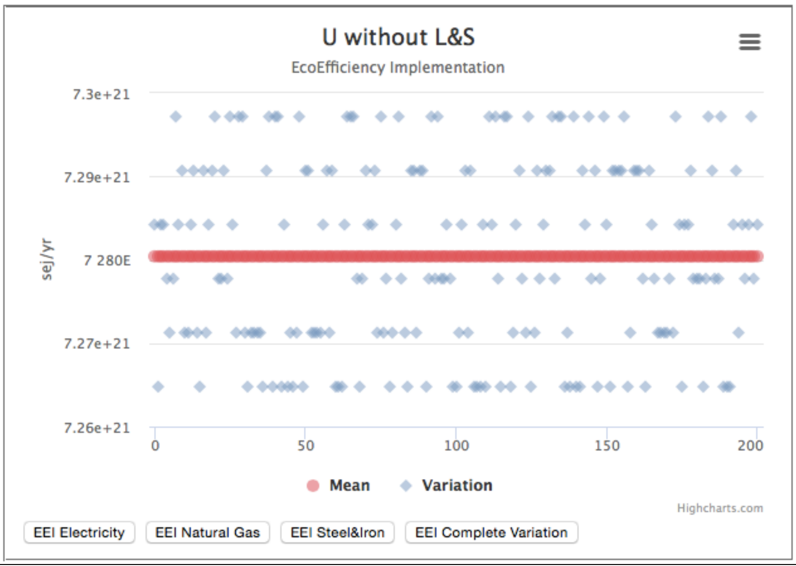
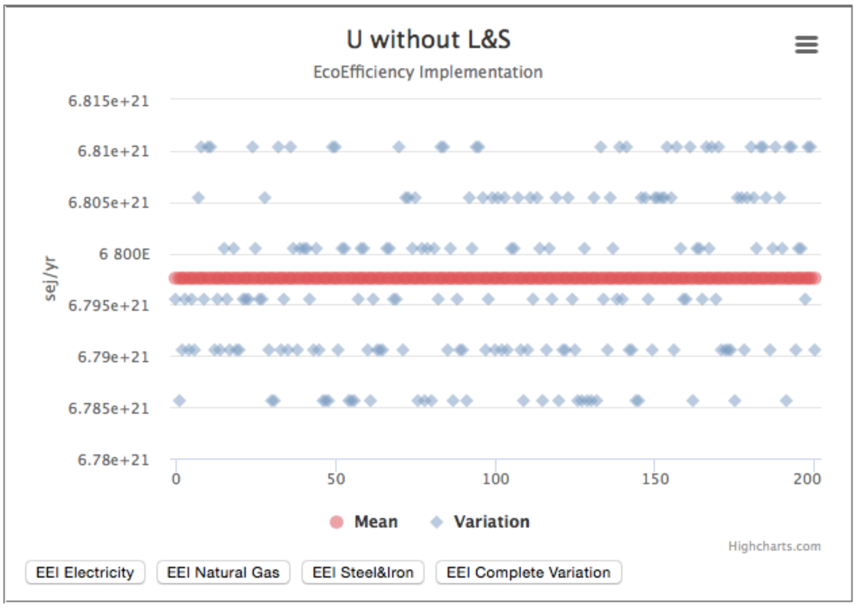


Figure 6.
EEI scenario of urban system, without L&S, in case only natural gas is managed according to EEI requisites (in this case, partially replaced by biogas from animal waste and wastewater treatment). Result (red line, average of all oscillations occurring) shows a value around 6.797 E+21 sej/yr**.**



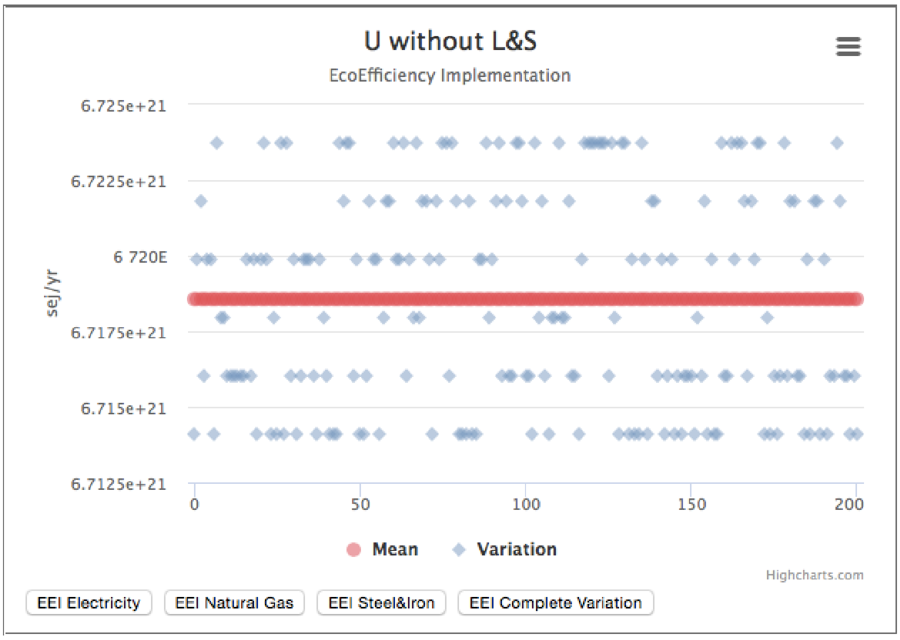


Figure 7. EEI scenario of urban system, without L&S, in case only iron&steel is managed according to EEI requisites (in this case, recycled and supported by photovoltaic electricity). Result (red line, average of all oscillations occurring) shows a value around 6.718 E+21 sej/yr.

Discussion: Significance for policy-makers, stakeholders and other researchers

Based on the above results, it becomes clear the the tool allows to re-process all the data concerning the resource use by the investigated system(s), in order to take into account their uncertainty and the different options available (scenarios).

First take-home message:

Administrators, managers and interested stakeholders can interact and stress the problems by testing together the available solutions and their resource and environmental costs. This allows the implementation of the participatory roadmap suggested in the Deliverable D3.1, preventing conflicts about solutions not sufficiently rooted in real data and performances.

Second take-home message:

The tool can become a way to "create" solutions, namely to verify all possible ways to save on resources through management, recycling, replacement, within a framework of collaborative discussion and precautionary principle. In particular, solutions based on better design of the system's operations as well as recycling and recovering of waste resources for their reuse in the process, may give rise to a new business model, the so called "circular economy", that can also be tested through the proposed tool.

WP4 deliverables: Energy efficiency analysis of socio-economic systems from and energetic metabolic perspective (the MuSIASEM approach)

D4.1. Characterizing Energy Efficiency from the Matrix of Production of Energy Carriers at the National Level

Giampietro M., Sorman A.H. and Velasco-Fernández R.

Executive summary

The issue to be explored

The concept of energy efficiency plays a key role in structuring the discussion and shaping the quantitative analysis used to inform energy policy. However, existing policies for reducing energy consumption and emissions, based on energy efficiency targets, are not effective in achieving the expected results. This failure can be explained by considering that while the term “efficiency” appears to be straightforward – the idea is to use less input for the greatest amount of useful output - on a practical and conceptual level efficiency is an ambiguous and problematic concept to implement in order to save energy and reduce greenhouse gas emissions. This is problematic because the way energy efficiency is measured depends on pre-analytical choices of: (i) “what” it is measured as “energy”; (ii) “how” to characterize in quantitative terms “energy uses”; and (iii) “why” the quantitative assessment is relevant (the purpose of the analysis). These pre-analytical choices entail scientific and political value judgements and entail the co-existence of different definitions of “efficiency”. Relying on individual “efficiency” measurements means assuming that we can identify the best course of actions by measuring a simple number – an output/input ratio calculated using just one of the possible definitions of “energy” at a given scale and in relation to just a given definition of relevance. This assumption has a detrimental effect on the quality of the choice of energy policies. In fact, it not only implies hypocognition (the missing of relevant aspects of the issue to be studied) but it also allows that the most powerful actors can cherry pick the specific output/input ratio - one of the possible indicators of energy efficiency - that best matches their agenda. Efficiency measurements are particularly problematic on a macroeconomic scale where a significant amount of meaningful information is lost through the aggregation of data into a simple ratio (e.g. Economic Energy Intensity).

In this deliverable we carry out a quality check on the usefulness of the concept of energy efficiency when applied to the study of the performance of technical processes and when used to generate indicators and targets used in policies related to sustainability.

What was done to investigate it

We used two approaches:

(i) a conceptual analysis based on a critical appraisal of indicators based on the know-how available in theoretical foundations of energetics – the disciplines that studies how to account energy transformations in self-organizing systems.

(ii) an empirical analysis confirming the validity of the concerns expressed in the critical appraisal. Actual assessments are used to illustrate examples of key aspects missed by the actual protocols of assessment of energy efficiency. These protocols entail comparing "apples" and "oranges".

3. The method employed;

In the section identifying the conceptual flaws making useless (and dangerous) the existing approach to energy efficiency we provide a crash course of energetics – i.e. how to properly account quantities of different types of energy forms interacting in a network of transformations.

1. Not all the joules are the same: what are the categories of accounting that should be used in energetics; how to handle differences in quality (1 J of electricity is different from 1 J of gasoline, and 1 kWh of peak electricity is more valuable than 1 kWh of intermittent electricity, etc.);

2. Flagging the fact that statistical offices are not providing a sound assessment of energy quantities - the assessments of the quantity of the "same flow of energy" in a given country are different when considering different statistical sources!

3. The deep epistemological challenge of assessing in quantitative terms the characteristics of "becoming systems" – the Jevons paradox – implies that a more efficient system will change, in the long term, its identity and behavior (it adapts to the improvement). It is impossible to predict the future consequences of increases in efficiency using deterministic/econometric models

As an alternative, we propose another approach to energy accounting – the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism – that can be used to assess the "performance" (not efficiency) of complex adaptive systems (such as societies). The MuSIASEM approach (that is applied in the other deliverables of this Work Package) is illustrated in relation to the possibility of carrying out an analysis across levels of analysis – i.e. the whole economy, individual economic sectors, sub-sector of sectors.

The data and sources;

The collection of information regarding Fund and Flow elements used in the energy sector has been obtained organizing data on non-equivalent acounting categories: (i) Primary Energy Sources (whether domestically produced or imported) and (ii) Energy Carriers divided in electricity, derived heat or fuels (whether domestically produced or imported). Data have been obtained from the following data sources:

1. *International Energy Agency* (http://www.iea.org/sankey/) organized in Sankey flow diagrams;

2. *Eurostat database* for specific data such as electricity, gas, petroleum products used in CHP and Heat Plants, Petroleum Refineries, Coke Ovens, Oil and Gas Extraction, Coal Mines and Nuclear Industry, the energy balances - [nrg_100a] (http://ec.europa.eu/eurostat/data/database);

3. *European Environmental Agency Greenhouse Gas Emissions* [env_air_gge] database for data on emissions for energy provision processes (Public Electricity & Heat Prod, Petroleum Refining and Manufacture of Solid Fuels and Other Energy Industries) (http://www.eea.europa.eu/data-and-maps/);

4. *Enipedia database* (http://enipedia.tudelft.nl) for data about Power Capacities and Power Generation Technology (fund elements) by country by fuel type. (more about enipedia in C.B.Davis, A.

Chmieliauskas, G.P.J. Dijkema, I. Nikolic (2015), Enipedia, enipedia.tudelft.nl, Energy & Industry group, Faculty of Technology, Policy and Management, TU Delft, Delft, The Netherlands).

The results

In the section identifying the conceptual flaws of the implementation of the concept of efficiency, we provide a series of practical examples showing that the concept of "efficiency" is simplistic and therefore it cannot be used to develop indicators and policy targets and indicators: (i) confusing reduction of consumption (e.g. because of an economic crisis) with an improvement of efficiency; (ii) the fatal attractor of mixing economic analysis with energetic analysis – the blunder of the economic energy efficiency indicator (EEI). We show that at the level of whole countries the EEI index is totally useless for comparing the energy performance of countries or studying the factors determining their EEI; (iii) in order to individuating factors explaining differences in the energy intensity of the economy one has to move to a lower level of analysis (at the level of economic sectors). Difference in the structure of the economy – the relative importance of the service and the industrial sector in the GDP – do affect the energy intensity independently of the efficiency of the technologies used in the economy; (iv) the openness of the economy and the massive reliance on credit leverage affect the overall assessment. Countries printing money and importing all the industrial products they consume will result less energy intensive than other countries. This has nothing to do with the efficiency of their technologies.

In the section presenting an empirical analysis we show the very high level of openness (dependence on imports) of the EU28 countries in relation to: (i) imports of Primary Energy Sources (fossil energy and uranium minerals); (ii) imports of energy carriers (liquid fuels and electricity). Using the MuSIASEM approach we assess the effect of "externalization" (a sort of technological foot-print) of the production of these flows for the various EU countries. Finally, we also address the issue of power capacity – the technical infrastructures needed to generate and make available energy carriers to the economy. This final section has the goal of illustrating the importance of looking not only at energy flows or stocks (how to change primary energy sources into of joules of energy carriers, or energy carriers into energy end-uses) but also to the required structural and functional elements making possible this transformations (e.g. power capacity and infrastructure in the energy sector). The analysis of this issue is done in general in economic terms – i.e. analyzing the required investments for changing the energy matrix, - but never in biophysical terms as we do.Significance of the results for policy-makers (usefulness for governance)

The discussion of energy policies based on single and uncontextualized efficiency indicators should be avoided due to the bias introduced by the pre-analytical definition of the definition of "efficiency" (reflecting the priority given to a specific concern). Instead, the discussion should be framed by considering a plurality of concerns to be addressed and translated into a set of non-equivalent definitions of "efficiency" referring to different criteria – moving to the concept of multi-level energy performance (multi-criteria and multi-scale analysis). In relation to this point, the adoption of the rationale of the metabolic pattern can dramatically help the tracking of flows of energy carriers looking at the two interfaces: (i) production of energy carriers - what type of funds (e.g. power plants, distribution infrastructure) are required in the energy sector to produce the different types of energy carriers – depending of the given mix of primary energy sources; and (ii) consumption of energy carriers - what type of funds (e.g. cars, trains) are required in the other compartments of the society to use energy carriers to do what. The rationale of metabolic patterning allows one to identify which energy carriers are used by specific societal compartments and then to associate them with specific societal functions.

Their significance for stakeholders

A transition to a low carbon economy can only be achieved if the society is capable of changing in a coordinate way the pattern of production and the pattern of use of energy carriers. If we keep looking and studying the problem of energy supply in isolation - considering it as a technical problem to be solved by engineers and technology – we will never find any effective solution. Generating new technological gadgets will not solve our problems of sustainability. Moreover, technological innovation allowing relative energy savings may lead to increases in energy consumption (Jevons paradox). We have to learn how to express a new set of social practices. Consequently, the rest of society has to be involved in the co-production of knowledge about how to move to feasible, viable and desirable metabolic pattern.

Their significance for other researchers (plausibility of scientific inquiry)

The challenge of energetics is the challenge of complexity. Energetics cannot be handled using reductionism (simplistic analysis). Complex energy metrics require the adoption of the rationale of metabolic analysis – i.e. applying relational analysis to energy transformations across levels and scales. There are several non-equivalent ways of accounting energy flows, all of which are needed to assess the performance of an economy. Three essential categories are: (1) primary energy sources (e.g., coal, wind, hydro, oil); (2) energy carriers (e.g., electricity, fuels, process heat); and (3) energy end-uses (quantitative characterization of what is achieved by the use of energy in relation to known social practices). Often these distinctions are not (properly) used in the development of policy targets and policy evaluations. Unfortunately, without a proper pre-analytical identification of the distinctions to be made in relation to the purpose of the analysis, it becomes problematic to have an effective analysis of the changes that a policy can generate when considering different criteria of performance. As shown by the failure of the Energiewende in Germany – where regulation and incentives to intermittent energy forms without a proper demand adaptation have prompt the use of coal power plants as peakers for stabilizing the net, increasing electricity prices and CO_2 emissions - not even kWh of electricity are the same!

The rationale of metabolic analysis makes it possible to associate a flow of energy (e.g. a given amount of food or a given amount of gasoline) to a given fund element (e.g. a person or a car) used to fulfill a goal (e.g. surviving or driving to a given destination). This makes the representation of a quantity of energy (a flow) much richer by contextualizing its assessment in relation to two converters: (i) the fund that has generated the flow; (ii) the fund that uses the flows; and (iii) a task – why the flow is processed by the fund. For example, if you have a given quantity of food energy you must have a fund that produced it (e.g. farmers using hectares of cropland) and a fund that is consuming it (e.g. dietary intake of people). The same applies to electricity, we need a fund that produced it (e.g. a nuclear power plant) and a fund that uses it (e.g. the appliances in the residential sector). Assessing the network of energy transformations using a combination of flow-fund relations – associated with a network of flows and a set of funds - provides a much more robust understanding of the problems than just discussing in terms of generic energy flows.

D4.2. Characterizing the factors determining "energy efficiency" of an economy using the multi-level end use matrix of energy carriers

Giampietro M., Velasco-Fernández R., Ripa M.

Executive summary

The issue to be explored

After accepting that the concept of efficiency is simplistic and therefore not useful for analyzing the performance of the set of energy conversions taking place in an economy (discussed in D4.1), it becomes essential to find an alternative approach capable of handling the complexity associated with energetics. In this deliverable we explore the option of using an innovative method of accounting of energy flows. The challenge is to track how different energy forms to be observed simultaneously at different levels of analysis are used in the society to maintain and reproduce the structural elements and express the various functions associated with the identity of a society. That is to say:

Who *is using these energy flows?* ***Why*** *are these energy flows used?* ***How*** *these energy flows are used?* ***Where****?* ***What*** *type of energy flows are we considering?* ***How much*** *of each type of energy flow is used? What* ***material standard of living*** *is associated with the use of these flows? What is the effect on the* ***employment*** *associated with the used of these flows? Can we link this multi-scale integrated analysis of the use of energy flows to* ***economic analysis****? Can we link this multi-scale integrated analysis of the use of energy flows to* ***demographic analysis****? Can we link this multi-scale integrated analysis of the use of energy flows to an analysis of* ***environmental impact****?*

Although this set of question represents a very "tall order" for an integrative accounting framework the answer given in this deliverable to it is that "***yes we can***" answer all these questions. The integrated system of accounting proposed in this deliverable can be used to characterize the energy performance of a society in relation to a set of different quality criteria. In relation to this point the deliverable illustrates: (i) the conceptual framework of the ***end use matrix***, that can be used to achieve this integrated set of answers; (ii) the specific protocols to be used to generate end use matrices; (iii) an application of this protocol to EU 28 countries illustrating the type of results that can be achieved.

What was done to investigate it

The investigation has been carried out in three phases: (i) Phase 1 illustrates the conceptual approach that has been developed: the *end-use matrix* allowing to establish a bridge between assessments of the energy performance of functional elements of the economic sectors defined at different levels of analysis; (ii) Phase 2 illustrates the protocol developed to generate *end use matrices* and the gathering of the required data for an application to EU28 countries; and (iii) Phase 3 illustrates the results and their significance.

The method employed

The end use matrix is based on the application of the Multi-Scale Integrated Analysis of Societal Ecosystem Metabolism (MuSIASEM) accounting framework to the description of the metabolic pattern of EU countries.

The data and sources

(i) Eurostat (2008) *Statistical classification of economic activities in the European Community. NACE Rev. 2*. Available at: http://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF.

(ii) Eurostat (2012) *Motor vehicle movements on national territory, by vehicles registration*. http://ec.europa.eu/eurostat/web/products-datasets/-/road_tf_vehmov.

(iii) Eurostat (2015a) *Annual detailed enterprise statistics for construction (NACE Rev. 2, F)*. http://ec.europa.eu/eurostat/web/products-datasets/-/sbs_na_con_r2

(iv) Eurostat (2015b) *Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E)* http://ec.europa.eu/eurostat/web/products-datasets/-/sbs_na_ind_r2

(v) Eurostat (2015c) *Energy Balances*. http://ec.europa.eu/eurostat/web/energy/data/energy-balances

(vi) Eurostat (2015d) *National Accounts by 10 branches - aggregates at current prices*. http://ec.europa.eu/eurostat/web/products-datasets/-/nama_nace10_c

(vii) Eurostat (2015e) *Population on 1 January by age and sex*. http://ec.europa.eu/eurostat/web/products-datasets/-/demo_pjan

(viii) Eurostat (2015f) *Stock of vehicles by category and NUTS 2 regions [tran_r_vehst]*. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Stock_of_vehicles_at_regional_level

(ix) Eurostat and Commission, E. (2015) *Energy statistics of the European Union: concepts and definitions on all flows ('aggregates') and products used in the Energy Statistics on quantities*. Luxemburg. Available at: http://ec.europa.eu/eurostat/documents/38154/4956233/RAMON-CODED-ENERGY-20150212.pdf/4814055b-de02-404a-b8e0-909fb82cbd54

The results

The energy end use matrix (Fig. 1) represents a useful tool to answer the set of questions described before and to evaluate the efficacy of policies aimed at achieving environmental targets, such as reduction of GHG emissions and economic competitiveness in an integrated and transparent way (as recommended in the Energy Efficiency Directive 2012/27/EU). In particular:

1. the energy end use matrix makes it possible to study the energy performance of a country simultaneously at different levels and scales of analysis (national economy, sectors, sub-sectors, sub-sub-sectors) by keeping the distinction between "primary energy sources" and "energy carriers", and within the categories of energy carriers between electricity, fuels and process heat;

2. it combines qualitative and quantitative variables into a multi-scale assessment obtained by keeping coherence in an integrated set of categories of accounting (fund vs flow elements) and data referring to different dimensions of analysis: biophysical, economic, socio-demographic data (it includes also hours of labor, gross added value, and economic energy intensity);

3. it makes it possible to bridge top-down (national statistics) and bottom-up (technical coefficients) information into a coherent multi-level assessment. In fact, it can scale quantitative information across

different levels of analysis by generating a “sudoku effect”. Non-equivalent assessments based on intensive (bottom-up – unitary processors – technical coefficient coming from engineering analysis – e.g. quantities of energy carriers consumed per hour of labor or per unit of output) and extensive (top-down – scaled processors – e.g. national and sectorial statistical data about the consumption of energy carriers per year) are integrated in the analytical accounting framework; and

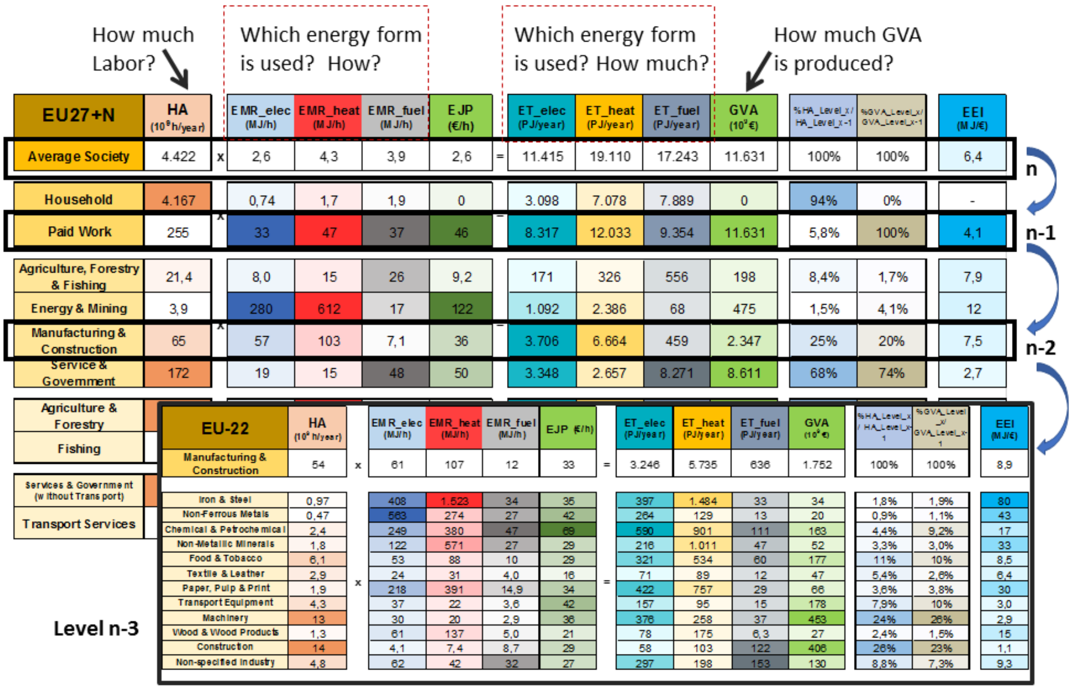


Figure 1: Example of energy end use matrix describing patterns of energy uses across levels - n = national economy, n-1 = paid work, n-2 = economic sector, n-3 = sub-sectors (e.g. within manufacturing)

4. it readily identifies the major determinants of energy performance – the overview given by the matrix makes it possible to identify the sectors, subsectors, specific processes using more or less energy and compare their performance with the analogous sectors, subsectors and specific processes in other countries. In this way it allows the framing of the discussion over the identity and robustness of the external referent of observed characteristics. Is the level of disaggregation of the data describing a sector or a subsector providing the required discrimination power to make a distinction between “technical energy efficiency” (determined by the characteristics of specific process) vs “effect of difference in economic structure” (determined by the different energy intensity of the mix of different technical processes)?

5. it makes evident the need of checking the level of openness of the considered sector/sub-sector/industry. Are the assessments of the energetic performance of sectors or subsectors referring to elements: (a) producing their output by using local primary sources?; (b) producing their output by importing raw materials?; (c) producing their output by importing semi-finished products as input; (d) just assembling finished components into the output they produce?

The deliverable provides an assessment of the performance of EU28 - as a whole, sectors per individual country and countries per individual sectors using end use matrices (45 tables and 34 figures).

The significance of results for policy-makers (usefulness for governance)

According to the 2015 *Energy Efficiency Directive implementation progress report*, EU Member States struggled to achieve their energy efficiency objectives. This led the Commission to lay down the 2015 'Energy Union Roadmap', aimed at reviewing the energy efficiency directives. However, the strategies are still based on targets considered one at the time, at their own scale of analysis without considering the broader (societal) context. No explicit relation has been established between the effects that changes in specific processes taking place inside specific parts of the whole economic process will have on the national or EU economy as a whole. By embedding the discussion of targets and policies within the general framework of the end use matrix is becomes possible to get the "big picture" of the context, the existence of unavoidable trade-offs and of biophysical constraints on the changes that can be done inside the matrix. In that sense, the end use matrix represents a transparent and useful scientific tool for deliberative policy making, recognizing and relating quantitative information linked to concerns of different actors that all deserve to be considered in democratic political debates. Last but not least, the end use matrix presented here is just an example of the potentiality of MuSIASEM the same approach can be adopted for dealing with other relevant issues such as the nexus of water, food or land use (for examples of this type of application see the MAGIC project).

The significance of results for stakeholders

The analysis of the energy performance of a society has to be based on the integration of a heterogeneous information space addressing the co-existence of multiple dimensions and multiple scales of analysis, all relevant when discussing energy policies. Stakeholders must ask both decision makers and scientists the adoption of more effective tools to be used to inform the debate on energy policies.

The significance of results for other researchers (plausibility of scientific inquiry)

An effective characterization of the national energy metabolism has to:

1. address four issues: (i) what type of energy is used; (ii) how is used; (iii) by which sectors is used; and (iv) why is used. The evaluation of energy efficiency policies should be based on the concept of multi-level energy performance;

2. characterize the *openness* of the various economic sectors and sub-sectors for assessing the effects of externalization on local performance. This require that data about the energetic performance of sub-sectors should be coupled to their level of imports;

3. identify the various factors determining the overall energy consumption of economic sectors. This task does require a re-organization of the categories used by official statistical accounting. That is, the assessments of inputs – i.e. energy carriers, labor and imports - and outputs – i.e. type of products – have to be organized over a classification of economic activities that should map as much as possible onto homogeneous production processes.

D4.3. The metabolism of Barcelona: characterizing energy performance across levels and dimensions of analysis at the city level

Giampietro M., Pérez Sánchez L., Velasco-Fernández R., Ripa M.

Executive summary

1. The issue to be explored

Within the activities of WP4 we first provided a critical appraisal of the concept of energy efficiency, simplistic for governance purposes, explaining why it should be replaced by the concept of energy performance (deliverable 4.1). Then, we proposed a solution to this problem by introducing and illustrating the concept of *end use matrix*, an effective method capable of handling the complexity of the information required for the characterization of the performance of energy uses in society (Deliverable 4.2). This deliverable addresses two additional research questions related to the possible use of the end use matrix to characterize energy performance:

(1) Whether it is possible to apply this innovative accounting method at the level of a city. This is an important point because the *end use matrix* could play a significant role in the booming field of analysis of urban metabolism. Moreover, by moving to a local level of analysis, the end use matrix allows the analysis of the implications of decisions related to the social practices expressed outside the market (e.g. leisure, caring activities taking place in residential or public space);

(2) Whether it is possible to provide a characterization of the metabolic pattern of social-ecological systems not only in relation to assessments of energy metabolized per hour of human activity (studying the rate of metabolism per hour of human activity) but also in relation to energy metabolized per unit of land use (studying the spatial density of the flows).

What was done to investigate it

We selected a case study – the urban metabolism of Barcelona – and then we applied to this case study the conceptual approach used for the development and generation of end-use matrix at the national level illustrated in Deliverable 4.2. The development of this application required a few adjustments to the original protocol originally developed for analysis carried out at the national level. Three important differences are: (1) the level of analysis is more localized and therefore, we had to adopt a more detailed set of categories of accounting in order to characterize structural and functional elements (e.g. activities inside the household sector). This has required a larger and heterogeneous set of data sources; (2) at the level of a city – especially in a city like Barcelona – quantities of human activity cannot be calculated "per capita per year" in relation to the size of resident population. In fact, the human activity associated with the presence of daily commuting workers living outside the city (50% of the working activity in the city) and of tourists (very important for the activities in the service sector) has a significant effect over the metabolism of the city; (3) the analysis of land use (the spatial location of the metabolic structure) required a new approach to the categorization, especially when considering that in urban building the "area used" inside the apartments, does not coincide with the "land used" by the building. A "multistory index" had to be introduced to bridge the two assessments. In conclusion, addressing these new features of the analysis (compared with the national end use matrices) have required: (i) the development of a new and more elaborated protocol for the generation of the urban end use matrix; and (ii) the need of expanding the sources of data, moving from a consultation of easy to obtain national statistics to the hunting of a myriad of local data sources, some of which are only available in the form of grey literature. For this reason, we had also to consult with local experts in the local administration to clarify doubts and double check the reliability of estimations and plausibility of assumptions.

The method employed

The end use matrix is based on the application of the Multi-Scale Integrated Analysis of Societal Ecosystem Metabolism (MuSIASEM) accounting framework to the description of urban metabolic patterns.

The data and sources

As mentioned the identification and the tracking of the sources of data required for this assessment, should be considered as one major achievement (result) of this study. The explanation of the data and the sources is given in Appendix 1 (a 34 page document!). In which the various sources are listed and their relations to the data used for the assessments are explained.

The results

1. This deliverable presents a reproducible protocol of accounting based on the concept of energy end-use matrix to assess energy performance at city level. The protocol allows identifying the factors determining the internal “end uses” of metabolized flows, who is using the flows, which flows, how much of each flow, defining characteristic benchmarks in terms of “flows per hour of human activity” and “flows per unit of area of built environment”. It can be applied not only to energy, but also to other flows such as food, water, emissions and waste. This is an important achievement because due to the extreme degree of openness of cities it is difficult to get a clear idea of the relations between processes taking place inside the city and processes taking place outside their administrative borders for providing the required supply of energy carriers.

2. This deliverable identifies the data required by the protocol and tests their accessibility. The analysis of city metabolism requires many different typologies of data from many different sources, which then need to be combined in a coherent and meaningful way to fill all the cells of the energy end-use matrix. Data requirements for the implementation of the accounting protocol and the possibility of gathering them were tested for the city of Barcelona.

3. This deliverable illustrates the potentiality of the end-use matrix approach for studying the energy performance at city level. The end-use matrix approach provides both the benchmarks describing the energy performance and the relative size of the various functional elements (e.g., port, transportation, air conditioning). It makes it possible to scale the quantitative information referring to either a functional or a structural element in relation to the city metabolism as a whole (i.e. it contextualizes the relative importance of particular energy efficiencies over the whole system). It tells how much the different end uses determine the overall metabolic picture of the city. For instance, how important is the activity of the port in determining its overall energy metabolism. The values of benchmarks for typologies of functional and structural elements allows an informed comparison with other cities that have different mix of functional and structural elements reflecting differences in relation to the weather, mix of economic activities, size of population, residential characteristics, etc. Moreover, the level of redundancy implied by the accounting method, the so called “Sudoku effect”, makes it possible to identify and handle problems related to the availability of data and/or missing relevant information. Finally, the self-explanatory set of relations used for building the end-use matrix represents a transparent and transdisciplinary analytical tool – it shows openly how the quantitative assessments are obtained- and therefore can be used to co-produce energy policy or knowledge about the performance of the city in a participatory and inclusive way.

The significance of results for policy-makers (governance)

After examining the Covenant of Mayors, an initiative promoted by the EU and signed by more than 6800 cities in 57 countries we identified three systemic problems that could be solved by the application of the end-use matrix: (1) The definition of generic objectives (e.g., "reduction of emissions" or "increase in renewable energy") is simplistic and difficult, if not impossible, to translate into specific policy targets across different types of cities; (2) The targets of the CoM should not be defined per capita due to the importance of the activity of commuters and tourists, and when looking only at absolute emissions/consumptions without considering structural and functional changes in the cities; (3) The assessment of emissions faces a systemic epistemological problem in that it should address direct, indirect, and embodied emissions in existing consumption. This requires addressing the co-existence of non-equivalent views of the metabolism: *the state* (what happens inside the city) and *the pressures* (what happens elsewhere to guarantee the supply and the sink capacity associated with the ability of metabolize the flows). The main message for policy makers is that the current problem-formulation and existing models used to inform policy have serious shortcomings for providing a meaningful analysis of 'sustainable city metabolism' – i.e. policy-makers could do better when choosing scientific evidence.

After examining two specific plans in Barcelona related to energy and climate: *Energy Improvement Plan* (PMEB) and *Energy, Climate Change and Atmospheric Quality Plan* (PECQ) we identified 3 systemic problems that could be solved by the application of the end-use matrix: (1) an abundant amount of detailed and relevant information is available for the city of Barcelona, but these data are not organized or used in a coherent way, within an integrative framework across different levels of analysis and dimensions; (2) within the elements determining the metabolic pattern of Barcelona we found a heterogeneity of specific situations and specific issues requiring specific solutions and specific policies. A 'one size fits all' solution for the sustainability problems of different cities simply does not exist; (3) any discussion about sustainability and notably changes in the energy end uses of Barcelona has "by default" a strong political dimension. Sustainability can be interpreted as a technical or political issue, or both. Ignoring the political option of changing social practices and looking only at the political option of adding new technical gadgets to stabilize the status quo may lead to both bad analyses and bad policies. The main message for policy makers is that a more effective multi-level integrated assessment based on participatory approach to the characterization of the performance of cities, looking at different dimensions and implications, is required.

The significance of results for stakeholders

The example of application of the end use matrix to the analysis of the metabolic pattern of Barcelona clearly shows that this approach makes it possible to adopt participatory approaches in order to check the quality of the narratives used to frame sustainability problems and to check the quality of the quantitative information used to inform the process of decision making. Stakeholders have to ask both decision makers and scientists that more effective tools be used to inform the debate on energy policies by involving them in the co-production of knowledge.

The significance of results for other researchers (plausibility scientific inquiry)

The most effective strategy for generating information useful for sustainability discussions may be to abandon the dream of producing 'evidence-based' policies based on simplistic quantitative indicators.

(i) When using generic targets at the local scale (e.g. efficiency of transportation in terms of MJ per tonne-km), no simple relation can be established between the effects achieved at the local scale and the effect that this change will imply at the level of the city as a whole;

(ii) When using generic targets at the large scale (e.g. the city as a whole), it is very difficult to know the implications of the achievement of these targets in relation to different attributes of city performance: quality of life, employment, emissions, economic growth, land use, etc. - defined at a lower level. For example, a radical cut of the supply of fuels and electricity would be the most efficient strategy to dramatically reduce emissions at city level, but nobody would propose this solution to solve sustainability problems. Sustainability policies are about deliberations over trade-offs and learning how to take compromise decisions.

(iii) Cities are open systems and the phenomenon of externalization makes any assessment of their energy performance tricky. Constructing indicators that ignore the fact that consumption and emissions depend on import/export may incentivize the adoption of cost-shifting strategies.

The main message of this deliverable is that insights from the field of complexity theory can be used to generate an information space based on relational analysis that can handle the epistemological challenges of multi-scale and multi-disciplinary assessment. The proposed approach has great potential for improving the quality of the process used to produce and use quantitative information to be used for deliberation over sustainability policies.

Not only the end-use matrix represents an innovative analytical tool because of its ability of bridging quantitative information across different levels of analysis but it also makes it possible to avoid other limits of conventional quantitative analysis:

1. Moving away from mono-scale and mono-dimensional analysis ("energy efficiency" of a city), toward multi-scale and multi-dimensional analysis ("energy performance" of a city);

2. Moving away from predicative representations, deterministic results that must be uncontested in relation to both definitions and assumptions in order to be usable, toward impredicative representations, contingent results depending on the choice of definitions and assumptions that can be deliberated in participatory processes;

3. Moving away from models providing representations chosen by the analysts, toward an approach generating representations co-produced with the users of the analysis;

4. Moving away from "dead quantitative assessments done once and for all", toward "living and flexible information spaces used for co-production of knowledge"

D4.4. Multi-scale integrated comparison of the metabolic pattern of EU28 and China in time

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Executive summary

The issue to be explored

This deliverable builds on the research line of Work Package 4: exploring the potentialities of the approach of the *end use matrix* to characterize the metabolic pattern of social-ecological systems in terms of energy performance, rather than in terms of efficiency. Within this line, this deliverable addresses three new research questions: (1) when moving the analysis based on the end use matrix to very large Social-Ecological Systems such as the comparison of the metabolic pattern of China and EU28, do we still get a meaningful integrated representation?; (2) can we carry out a comparison in time (2000-2016) of two metabolic patterns of social ecological systems while observing it simultaneously at different levels and scales of analysis across non-equivalent descriptive domains? What types of problems are encountered with this analysis across levels? What type of insights can be obtained developing a decomposition analysis of metabolic indicators from multi-scale fund-flow approach?; (3) can we explore the implications of externalization on the stabilization of the metabolic pattern of social-ecological systems and on how does it affect its overall performance? Put in another way, can we identify the factors determining the stability of societal metabolism in relation to the terms of trade?

What was done to investigate it

This study required addressing and solving a few methodological and practical problems:

#1 - solve the problem generated by the different categorization of data used for the accounting when using data sources from Europe and China;

#2 - solve the problem of lack of consistency of data across the historic series (2000-2016) – not all the data were available for the chosen set of years, so we had to interpolate a few data in order to have three complete datasets over the three chosen years;

#3 - decide how to visualize the very rich dataset obtained as result of our analysis: data referring to different years, different social-ecological systems observed at different levels – e.g. whole economy, individual sectors, sub-sectors (the deliverable has 99 figures and 23 tables!);

#4 - develop a method of decomposition analysis (multi-scale fund-flow decomposition analysis – described in Section 2.1.3) to study the factors explaining the differences and the changes in the metabolic characteristics of EU and China over the considered period of time, when observing their functional elements across different levels;

#5 - develop and apply a method for assessing the effect of externalization on the metabolic pattern of EU27 and China.

The method employed

The end use matrix is based on the application of the Multi-Scale Integrated Analysis of Societal Ecosystem Metabolism (MuSIASEM) accounting framework to the description of the differences and changes of the metabolic pattern of China and EU27 in the period 2000-2016 observed at different levels of analysis. A multi-scale fund-flow decomposition analysis and externalization have been developed and applied within the MuSIASEM rationale. Some visualization of the relational analysis compressed in the EUM over time have been made using Gapminder Tools Offline (www.gapminder.org).

The data and sources

European data: *European Energy Balances* (Eurostat, 2018b); EUROSTAT *National accounts employment data by industry (up to NACE A*64)*; EUROSTAT *National accounts aggregated by industry (up to NACE A*64);*

Chinese data: *Census of the People's Republic of China*; *China Statistical Yearbook*; *China Labour Statistical yearbook*; *China Energy Statistical Yearbook*.

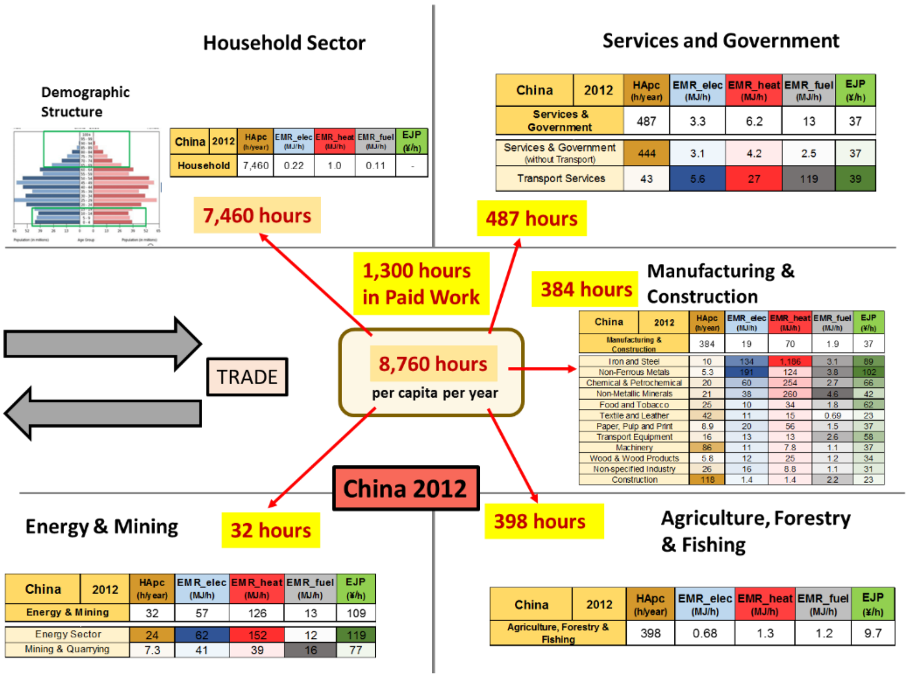
Embodied resources in trade were calculated using the EORA 26 v199.82 database for the year 2012 (Lenzen et al., 2013, 2012).

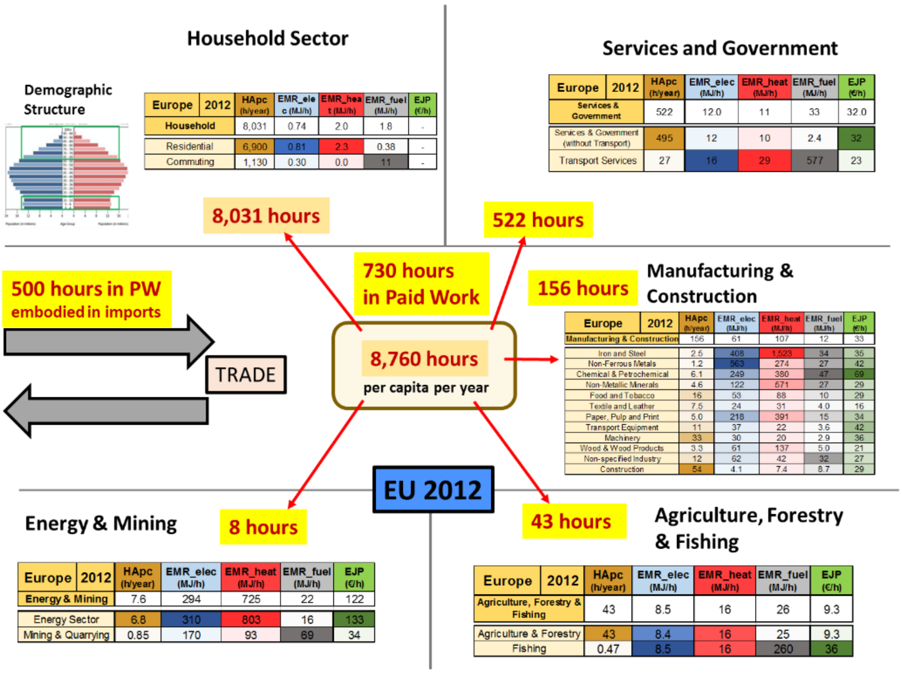
The results

When adopting a metabolic narrative, differences in energy uses at the level of the whole society can be explained not only in terms of: (i) differences in the technologies adopted; and (ii) differences in the economic mix, the relative importance of the service and industrial sectors. Two other key factors must be considered: (iii) differences in the metabolic phase of the trajectory of evolution of the economy. That is, this narrative makes it possible to contextualize the performance of the whole economy inside an expected evolutionary path. Using the analogy with the actual metabolism of human beings, in order to assess the energy performance of a given organ of a person, e.g. the heart, we have to know whether the organ is operating in an adolescent (e.g. an economic sector operating in China in the comparison) still building body mass (industries and infrastructures), or in an elderly person (e.g. an economic sector operating in EU, a post-industrial society); (iv) difference in the level of openness – keeping the analogy with human metabolism, a woman that is pregnant producing body mass for another human being will consume more than an old woman. In this study we have shown how the flow of industrial imports from China helps the EU28 to keep an economy mainly based on the service sector.

China and EU28 are two quite different economic systems operating in a different stage of their evolutionary trajectory as economies. By using a metabolic narrative we can identify the factors determining their differences: (i) a different size and structure of the population; (ii) different values in the benchmarks describing the metabolic pace of their different organs, with EU28 having consistently much higher values across the set of organs; (iii) a different profile of the relative size of their organs, China having a much larger industrial sector and a much smaller final consumption sector; (iv) a different level of externalization: EU28 externalizes industrial activities to China through imports. On the contrary China has a large industrial sector not only because of the need of further capitalizing its own economy and generating the required infrastructures of a modern country, but also because it exports goods to the rest of the world.

The four factors that can be used to explain differences in the energy performance of EU28 and China have been changing quite rapidly in the last two decades: (i) the population of EU28 is ageing and this is opening the door to immigration, the population of China has an extremely high share of adults in the work force, because of the legacy of the 1 child policy; (ii) the metabolic pace of energy consumption per hour is several times higher in EU28 than in China for many of the considered sectors (organs); (iii) whereas the industrial sector is getting smaller and smaller in EU28 both in terms of share of work force and GDP, it is very important in the Chinese economy; (iv) EU28 is dependent on imports for energy, food and a lot of industrial products, whereas China is an exporter of industrial products and its dependence on imports for food and energy is much smaller than EU28. Unless we adopt an analytical tool-kit capable of explaining how the overall performance of EU28 economy and China's economy are affected by the differences and ongoing changes in these four factors, it is very unlikely that we can get useful insights from the comparison. This is an option provided by the approach proposed here.





The two figures above illustrate the different patterns of energy uses and human time allocation on the different functional sectors of China and EU economy. In spite of having 1,300 hours of paid work per capita per year China has a lower number of working hours (488) in the service sector than EU28 (522). The large service sector in EU28 can be explained by its dependence of imports: 500 hours of paid work are embodied in the imports, allowing a dramatic reduction of labor allocation in the local primary sectors (AG and EM) and Manufacturing.

The significance of results for policy-makers (usefulness for governance)

Decision makers should make an effort to: (i) improve the robustness of knowledge claims by differentiating the portfolio of approaches to modelling used to inform policy choices. Conventional CGE models of integrated assessment should be complemented by innovative models addressing the epistemological predicament associated with the existence of non-reducible descriptive domains, the co-existence of multiple scales and multiple dimensions of analysis. Talking of elephants missed when using existing indicators, China is using almost 1,300 hours of paid work per capita per year in its economy, whereas EU28 is using around 700 hours of paid work p.c. while the performance of these two economies is still studied and compared using aggregate economic indicators "per capita"; (ii) improve the transparence of models making it possible the co-generation of knowledge claims with the users of the results of the models. The transparency of both models and data was a hot issue discussed in the Energy Modelling Platform for Europe (EMP-E) 2018 that is gaining a growing attention both in the European Commission and in the community of practitioners – e.g. the open energy modeling initiative (https://forum.openmod-initiative.org/).

The significance of results for stakeholders

The material presented in this deliverable suggests that an approach based on the analysis of the metabolic pattern can provide additional pieces of information to the discussion over sustainability. These additional pieces of information would allow an informed discussion of the proposed policies in terms of: (i) desirability, in relation to the material standard of living; (ii) viability, in relation to technical and economic aspects; and (iii) feasibility in relation to external constraints outside human control.

The significance of results for other researchers (plausibility of scientific inquiry)

A multi-scale and multi-dimensional analysis can look simultaneously at the characteristics of the whole and at the characteristics of the various “organs” expected to operate inside social-ecological systems. In this metabolic narrative, differences in the performance of the different organs can be explained in two different ways: (1) because of the identity of the whole – i.e. the expected characteristics of the organs of a young economy still capitalizing vs an adult economy ageing; (2) because of the identity of the specific organs – after having defined an identity for a metabolic system (e.g. young and old people, men or women) we should expect different metabolic characteristics for different typologies of organs. In the analogy with the societal metabolism, when considering different typologies of economies, we can always expect to find that the metabolic characteristics of household sector are different from those of the energy and mining sector. This new narrative about the energy performance allowing the identification and quantification, across different dimension of analysis, of new aspects useful to explain the observed metabolic characteristics missed by conventional analysis.

WP5 deliverables: Consumers and energy efficiency

D5.1. Stock taking of instruments targeting household energy efficiency

Trotta, Gianluca and Lorek, Sylvia

Executive summary

The issue to be explored

The focus of WP5 is households as the main final consumer of energy. Reducing final energy consumption has long been advocated as a strategy for minimising primary energy use through consumer information campaigns, promoting more efficient technical appliances, labelling energy efficiency etc. According to the International Energy Agency, household energy efficiency improvements have the potential to support economic growth and social development, to improve occupant health and well-being, and to enhance competitiveness and investment opportunities.

As known the dominating fields of household expenditure affecting energy consumption are mobility and food supply (external) and heating and electricity for operating household appliances (in-house consumption). As mobility and food supply are policy fields distinct from energy policy, we focus on residential energy consumption. Thus analysis undertaken was to identify which tools have been used at the EU level and within selected member states) to improve residential energy efficiency.

What was done to investigate it

The report combines overarching European data with information gathered in the case countries. The analysis was focussed on five countries: Finland, Hungary, Italy, Spain, and the UK reflecting North and South Europe, relevant regarding heating, as well as East and West Europe representing a legacy of pre-unification planning and construction. Additional information are available from the country studies covering Germany, Latvia and Romania (all on the project homepage).

The EU Directives (e.g. EED 2012/27/EU) are setting the policy framework for domestic energy policy in the EU and provide the basis for diverging national policies. Consequently, a first research question was the effectiveness of the EU regulatory framework, followed by how they had been implemented and thirdly, which additional measures had been taken on the national level. As the far largest share of energy used in households is on room heating and hot water, building specification, and heating system become immediately relevant. Therefore the possibilities to improve efficient heating take centre stage in this report. A separate section is devoted to electrical appliances.

Analysing how households can contribute to more energy efficiency leads to the questions how households can be supported by other market players and actors. We identified the potentials of traditional stakeholders such as housing companies, banks or research have, plus emerging stakeholders such as Non Governmental Organisations (NGOs), Municipalities' Energy Providers MEPs and Energy Service Companies (ESCOs), and the role new tools such as Energy Performance Contracts (EPCs) might have. In the case of business and civil society initiatives the main objective of the report is to illustrate diversity, not to provide a complete overview of all existing initiatives.

The method employed

This stock taking report has been compiled as a result of desktop research regarding the EU regulatory framework, and on the country studies. Promising strategies were selected from the country studies based on assessment if they addressed the key physical, social, and behavioural obstacles to increasing domestic energy consumption. Since this report is based on country data, we do not discuss which obstacles should have been addressed by what means, but describe which obstacles have been addressed by which measures. Moreover, we analyse the role of the private sector in stimulating the investments in energy efficiency and complementing European and national public policies. In conclusion, we offer some hypotheses explaining obvious policy failures on the national level, indicating where there is room for improvement, and draw some meta-level conclusionsfor EU residential energy policies.

The data and sources

The country reports have been compiled with the help of national experts. They had not only the language capabilities to analyse national language information material, but also the knowledge of where to find appropriate information. Additionally, in some cases, the collection of information has been supported by interviewing external stakeholder with expertise in the residential energy sector and energy efficiency. The report analyses the trends available on ODYSSEE/Mure database, Eurostat and National Statistics databases complemented with data on residential building stock taken from national statistics from a legislative and economic perspective. This is because of the strong correlation between dwelling characteristics—age, tenure, type, size—and the energy consumption and thermal efficiency performance of buildings, in addition to household composition, income, and behavioural traits. The collection of information was concluded by end of November 2015.

One of the sources used are the National Energy Efficiency Action Plans (NEEAPs, third version of April 2014). Following European obligations, EU Member States have submitted their plans, and the measures mentioned and the different levels of policy implementations have been analysed and discussed for this report. The in-depth analysis of the third NEEAPs and other national policy documents is supported by additional literature sources. Main EU laws, policies, and related documents were taken from public sources, mainly the EU law database.

The results

All European Member States analysed are committed to doing more on energy efficiency at all stages of the energy chain – from the design of houses, cities and grids, to the behaviour of consumers. So far most of the energy efficiency policies have promoted the technical efficiency through technical standards of buildings or incentive for investments in energy efficiency appliances and energy consuming equipment.

Country perspectives

Compared to other analysed countries, the UK government's set of energy efficiency policies lately targeted at the residential sector appears to be more effective. Its more balanced character, together with the participation of and obligations for private actors have been decisive for this relative success. Legal obligations placed on energy suppliers to deliver domestic energy efficiency programmes are part of a holistic policy package with a medium-term framework addressing many aspects of energy efficiency in the residential sector. The motivation for this ambitious approach appears to be a domestic one: the UK residential energy sector is more problematic than the EU average. The prevalence of older dwellings in the national stock, built to lower standards of energy efficiency, combined with a high share house ownership among the less affluent sectors of society and the dominant role of the private sector in the housing rental market leaves larger untapped potential for improvements than in the other countries under investigation. Due to significant energy efficiency improvements since 2007, the energy use by households in the UK was in line with the EU average in 2015. It is unclear how Brexit will influence energy efficiency policies in the UK.

In Finland, improvements in the residential sector seem not to have been a priority for policymakers, despite its highest energy consumption per capita and the highest space heating demand per dwelling in Europe. Beyond a general tax reduction for any household services, no real economic incentives have been provided to stimulate energy efficiency investments in the last years, and fuel poverty as well as the landlord-tenant problem have not been sufficiently taken into account in the national energy efficiency strategy. Therefore, the residential energy consumption per stock of permanently occupied dwellings did not decrease within the period 1995– 2015. One possible explanation is the policy makers' focus on the energy intensive industries.

Also in Spain, the residential energy sector seems not to have been at the top of the energy saving agenda; instead, the attention has been focused on the transport sector representing about 40% of the energy consumption. But as opposed to Finland, in Spain the residential energy sector is one of the most efficient in Europe, mainly because of the modern building stock and the low level of space heating demand. In addition, with the State Housing Plan 2013–2016 and the PAREER-CRECE Programme, both the national and local governments have recently allocated a significant share of the budget for energy efficiency and saving projects to inhabited residential buildings.

In Hungary, with the Warmth of the Home Programme, the government provided financial incentives to households ranging from the replacement of inefficient appliances or obsolete facade doors and windows, to complex energetic refurbishment of blocks of flats. The funds allocated to this policy measure were rapidly exhausted indicating the programme was underfunded as compared to demand. To increase energy awareness, large-scale educational programmes targeted to specific groups have been provided by both the government and the energy providers E.ON and ELMÜ-ÉMÁSZ. However, there is still room for improvement: implementing policies incentivising energy efficiency investments could reduce domestic energy consumption, alleviate fuel poverty, and improve health and thermal comfort, while reducing the dependence on Russian gas.

Italy offers some interesting policy initiatives in terms of fiscal and financial incentives. The tax deduction scheme (since 2007) has proven to be very effective in attracting more investments than what it actually cost in terms of foregone fiscal revenue. In addition, since 2012, the Thermal Account has provided substantial incentives for energy efficiency investments. Subsidies covering part of the expenses for renovation will be available until 2021. Benefits from these policy measures are partially exploited by ESCOs. These measures and activities may have contributed to curb the negative trend of energy savings. However, these measures have not been developed into a comprehensive policy package addressing all the aspects of the residential energy sector.

European perspectives

Despite a shared ambitious EU residential energy policy adaptation is lacking behind. The different levels of per capita or per dwelling household energy consumption are to a large degree influenced by policies of the last decades, as the housing stock is a lasting legacy. More recent explanations were found in Spain and Finland—in both countries governments focussed their climate mitigation efforts on other, more dominant sectors, transport in Spain and industry in Finland. Furthermore, economic dynamics play a role: the recent construction boom in Spain led to a significant share of the housing stock built according to advanced energy standards, unlike in the UK or in Finland.

However, whether the common European or the national targets on energy efficiency will be reached is not beyond doubt. What looked well in numbers at the time of taking stock (ending 2015) might just be influenced by reduced economic activities in the aftermath of the Great Recession while not reflecting true efficiency gains. The EU State of the Environment Report due in autumn 2019 will provide the data which emerged after the data collection for the project had ended and which are necessary to distinguish structural reductions from effects of the economic cycle.

Their significance for policy-makers, stakeholder, and/or other researchers

Energy efficiency policy design matters, if only in terms of meta-level criteria: an optimal policy strategy for improving energy efficiency in the residential sector should seek to impact different barriers and target segments through a holistic approach pursuing multiple goals coherently, mutually supporting each other. As the barriers are diffuse and policy mechanisms rarely operate effectively in isolation, such an approach must be based on a careful analysis of the local and national situation. Only then synergies, making the combined impact larger than the sum of isolated effects, may be realised. This implies that a comprehensive energy efficiency policy strategy is determined by the degree to which the design of policy mixes address the barriers identified.

The analysis of the different policy instruments indicate the importance of EU initiatives (mainly in form of the directives) to move countries towards energy efficiency. For reaching the emission targets of Paris Accord, adapting the directives will be a key policy tool. The huge variety of approaches that can lead to successful steps. Most effective are policy mixes, combining regulatory approaches with economic incentives and product specific instruments. Amongst the regulatory approaches, legal norms are immediately effective and applicable on a broad scale, while information instruments not necessarily lead to behavioural change on a broader scale. Economic incentives, grants and subsidies, loans, tax and tariffs, all are potentially effective, depending on the context of their application. Product specific instruments from labelling to eco-design can complement legal and economic instruments. Time counts as well: an energy efficiency policy package tends to be more effective if it is maintained over the long-term.

In addition to policy packages, engaging the private sector is acknowledged as being central to ensuring long-lasting impact. As such, private initiatives do not duplicate governmental energy efficiency measures in the residential sector, but rather augment and strengthen them. A long-term policy horizon is a necessary, but not sufficient condition for mobilising private investments in energy efficiency in the residential sector. Rethinking of business models is crucial, and is still challenging. In their current business model, energy providers cannot decouple utility profits from energy volumes and energy service companies do benefit from economies of scale when selling energy efficiency solutions to households. New business models would have to include providing loans, investment and implementing demonstration programs for alternative solutions to low-energy buildings. Mainly practical exchange with citizens leads to the required changes.

D5.2. Identification of promising instruments and instrument mixes for energy efficiency

Spangenberg, Joachim H .

Executive summary

The issue to be explored

Households are one of the major energy consumers in the EU, and haves not yet exhausted their enormous potential in fulfilling the EU energy policy objectives. Within households, low temperature heat generation for room heating and warm water holds by far the largest share in energy consumption. The heat sources are varying between households and Member States; they include coal, oil, gas, wood and electricity. Electricity use for lighting and household appliances is much less important, but has received a disproportional share of public interest and support by the EU.

Analysing energy efficiency contributions of households requires taking system effects into account. For instance, replacing individual stoves by electric or district heating will have different effects depending on the energy provision system into which the house-hold is embedded, and recommendations for household choices must take those differences into account. Thus like for efficiency, the system matters for carbon intensity: the relation of final energy consumption to primary energy consumption is to a large degree determined by the system (see WP 4).

Acknowledging this diversity, we refrain from suggesting any best practice or standard policy measures but analyse which instruments have addressed which causal factors, and – as far as information is available – how effective they have been under specific circumstances. The recommendation is then not one of a specific policy mix across Europe, but of a policy toolbox.

What was done to investigate it

We classified policy strategies intentionally addressing a number of objectives described in the next section as ‘promising’. Policies supporting technical innovations for energy efficiency of buildings are also considered as part of the ‘promising’ category. Finally the physical minimum demands of making buildings more energy efficient are also used as a yardstick to identify policies which are not promising, or even counterproductive, be it in a planning, economic/fiscal or other policy context.

Policy strategies supportive of enhancing the overall efficiency of household energy consumption are part and parcel of many but by far not all National Energy Action Plans. For national implementation a variety of means can be chosen as long as they pursue and reach the same ends. This rules out the existence of any ‘silver bullet policy mix’, and so does the diversity of climatic, building and institutional settings. If and how these conditions can be fulfilled in everyday life depends on a multitude of factors, such as the age and structure of dwellings, settlement structures, planning processes, income levels and human routines, habits, norms and preferences, but also external factors like climate and institutions/administrative traditions. Especially social norms are hard to influence by climate and energy related policies, and are thus hardly addressed in the context of energy efficient dwellings. This is easier in the case of buying household appliances influencing the household electricity use. Their assessment follows different but related rules to those for heat consumption and is discussed in a separate section of the report.

The method employed

To minimise energy consumption while maintaining a good supply of energy services, in particular in terms of low temperature heat, a household must confirm to a number of physical, social and behavioural conditions. In particular, a building must fulfil the condition to be

i. capable of keeping heat within the building envelope, by means of isolated walls and roofs, adequate windows, doors and shutters;
ii. built in a heat conservation and appropriation supporting way, based on local or regional planning (governance);
iii. equipped with service providing installations requiring only low inputs;
iv. offering energy security; as standard heat storage tanks offer supply for about 2 hours per m^3 of storage, external supply or in-house fuel storage must be available;
v. used accordingly, which required adequate behaviour based on relevant knowledge, motivation and skills (management);
vi. part of an efficiency enhancing energy supply system.

The first three criteria primarily address the physical characteristics of the building, and since based on physics, they are the same throughout the European Union. The fourth criterion, although formulated for reasons of service reliability, is similarly phrased in physical terms. Criterion five refers to the adequate use of the physical structures, and in our analysis on the information provision for this behalf. Finally, the sixth criterion addresses the overall energy supply system in which the households are embedded.

The data and sources

This report is based on different data and information sources, in particular on eight European country reports (Finland, Germany, Hungary, Italy, Latvia, Romania, Spain, and the United Kingdom) covering a wide range of policies and private initiatives addressing energy efficiency in the residential sector (see D5.1 and Annexes). The country reports have been compiled by national experts provided with the capabilities to analyse national language information material, but also the knowledge of where to find the appropriate information. In some cases the collection of information has been supported by interviewing external stakeholder. Main EU laws, policies, and related documents (e.g., the Energy Efficiency Directive 2012/27/EU) were taken from public sources, mainly the EU law database (URL: http://eur-lex.europa.eu/homepage.html) as the basis for assessing the policy impact role of EU regulations, the third National Energy Efficiency Action Plans (NEEAPs) and other national policy documents.

An extensive use was made of the ODYSSEE database which contains detailed data on energy consumption and related CO_2 emissions. ODYSSEE data on energy consumption are complemented with data on residential building stock taken from national statistics databases. This is because there exists a strong correlation between dwelling characteristics – age, tenure, type, size – and the energy consumption and thermal efficiency performance of buildings, in addition to household composition, income and behavioural traits.

The results

The achievable effect of energy efficiency policies depends not only on the local or national circumstances and the policy instruments chosen, but also on the design of the instrument and the process of developing, implementing and adapting it, to degrees varying with the situation.

Selected general success factors include

- Using an instrument mix with special emphasis on building energy codes. They include e.g. energy performance standards, minimum thermal insulation standards including glazing and airtightness, and standards for the efficiency of fixed building services such as heating, lighting and controls. Such regulatory policies have been found to have more impact than financial or informative instruments.
- Effective multi-level governance permitting lower levels to test means of implementation in a niche, with the perspective of scaling up. Scales reach from neighbourhood plan and local plans to reginal, provincial and national plans.
- Competitive markets as a condition for informal and fiscal/financial incentives to be effective; in oligopolic markets e.g. in the construction sector new buildings are rather are set up following established practice than making use of best available technologies BAT.
- A national space standard limiting continuous growth of flat sizes is a main tool for limiting the energy consumption per household and to avoid the overcompensation of efficiency gains by increased heated area. Building standards and fiscal measures might be used to implement it.

Furthermore, some success factors are instrument-specific, such as

Standards

Standards need to be monitored and updated regularly to remain in touch with technological developments. Emphasising the best available technology BAT or – even better – the state of science and technology in building standards can introduce an inherent dynamic, like the top- runner approach can do for electrical and other appliances.

Economic instruments

Economic incentives must be high enough to be effective, making investments into energy efficiency profitable. They should be targeted at actions which are cost effective from a collective point of view, e.g. avoiding externalised cost, but which would not otherwise have been undertaken by consumers. The level will be differing between countries, mainly according to disposable income levels, if households are the investors. Profitability can often not be achieved efficiently with one policy instrument but requires a combination of several tools such as grants, reduced interest (soft) loans and tariff reductions. Such packages can be effective incentives for measures to be taken by economic agents, beyond compliance. Subsidising energy audits and the purchase of highly efficient appliances can also be an incentive, but could also be offered by banks as soft loans, repayable from the energy savings. In order not to lose effectivity, fiscal incentives should be dynamic, linked to the overall income index and must be set in a socially responsible manner. Instead of lowering energy prices for social reasons, adapting transfers and maintaining the efficiency incentive seems to be more promising without reducing social security (a package concept).

Education and information

Consumer education should focus on making people familiar with energy sensitive behavioural routines and practices, in particular in the use of heat (for room heating and warm water).

Communication linking efficiency to modernity or other fringe benefits might be more effective than emphasising energy saving potentials. Training measures should not only target households and their in-house energy management, but also enhance the qualification of local authorities supervising standard implementation, and the respective businesses.

As this overview of success factors has illustrated, energy efficiency improvements in the residential sector differ significantly between countries, be it EU Member States or beyond. No country can claim to “have it all got right” – there is ample opportunity for learning from each other.

Their significance for policy-makers, stakeholder, and/or other researchers

Using energy efficiency to enable lower energy prices for households and industry (Romania), pursuing the reduction of energy cost (Finland) and considering energy price a matter of competitiveness (Hungary) are counterproductive to reducing household energy consumption, contributing to falling short of implementing the EU targets. Economic considerations should not neglect the fact that instruments such as energy efficiency standards (e.g. EPBD) and energy pricing have been one of the main drivers of innovation. Most MS implement the directive and nothing but the directive, only few set a number of more ambitious targets (Hungary, Italy, Spain, Denmark). As the directives lag behind what is technically possible and environmentally desirable (in particular after the Paris agreements), sharpening the standards in the coming revision is advisable.

A serious obstacle to achieving improved energy efficiency in the residential sector is house owners’ experience of excessive administration and procurement procedures, delays and cost. Reliance on informational methods seems to be insufficient – but can accompany other tools to enhance public acceptance. Economic incentives can be effective, but carry the risk of regressive effects. Enhancing social distribution problems can put energy efficiency policies at risk. In such cases, regional and social targeting may increase the standing of energy efficiency policies.

Other significant lessons refer to the process of policy development and implementation:

- Stakeholder participation in design and implementation of policy measures helps public acceptance and easy implementation.
- Continuous revision and improvement of an instrument during the implementation phase: Regulatory mechanisms need to be monitored, evaluated and updated regularly to remain in touch with societal trends and technical developments.
- Smart integration of policy instruments into effective policy packages: larger energy savings are potentially possible if measures aiming at technical, infrastructural and behavioural improvements are applied in combination, mutually reinforcing each other.
- A building code or other forms of rules signalling the future direction of building regulations in relation to carbon emissions from, and energy use in homes can provide more regulatory certainty for the homebuilding industry, investors and households.
- Easy procedures for changing energy suppliers can be an effective support in a competitive market, but need to be supported by information about both the possibilities and the performance of different sup-pliers. National regulation should make sure that efficiency-conscious package deals carry the best economic bargain.

D5.3. Stocktaking of social innovation for energy sufficiency

Lorek, Sylvia and Spangenberg, Joachim H.

Executive summary

The issue to be explored

Energy sufficiency is an issue only gaining prominence in more recent discussions. However, as we have seen in previous deliverables, it is of crucial importance to mobilise consumers and help refocus discussions on sustainable consumption from consumption patterns to the decisive consumption levels. As efficiency gains are not compensated but significantly reduced by rebound effects, sufficiency is needed to counteract this mechanism: sufficiency is needed to make efficiency effective.

Sufficiency or enoughness is a normative approach postulating upper and lower limits of consumption, for environmental and for social reasons. It is addressing the general sociotechnical environment of energy use on three different levels of decision making:

- policies are called upon to set suitable framework conditions and mechanisms (one example in the literature is combining a free basic energy supply with progressive pricing of energy consumption to address both the upper and the lower boundary conditions);
- society is urged to adapt preferences, value systems and orientations which are produced and reproduced in the interaction of individuals, peer groups and the wider social environment; and
- individuals are encouraged to change their behavioural practices, intervening in societal discourses and value developments, and change their behaviour as far as it has been squandering resources/energy and can be done on the prevailing material and social settings. Voluntary simplicity can play a limited role on this level.

Most sustainable energy consumption strategies so far have focussed on information and awareness raising through campaigns, i.e. the third bullet point, together with fiscal measures to enhance the attractiveness of energy saving and overcome obstacles. However, the effects of such strategies have been well below expectations, a phenomenon known as 'insight-action gap'. This is the reason why the conceptual basis of such efforts, which are mainly based on the Theory of Planned Behaviour, needs to be re-thought as well; Social Practice Theory offers a new concept not only addressing planned decisions but the daily routines of household behaviour, claiming that consumption is just the tip of the iceberg and a broader approach is needed to change it. It focusses on the second, and to some degree on the first bullet point.

What was done to investigate it

Given the twin challenge of renewing the conceptual base and refining the sufficiency concept on this basis, this deliverable has two complementary parts, a conceptual and an empirical one; both have been developed further after submission of this deliverable and been published as separate papers. However, as minimum conditions (sufficient resource access for a healthy livelihood and an active participation in the respective society) vary between countries, and in most cases are more or less adequately addressed by social legislation, we focussed more on the overconsumption aspect for which so far hardly any policy tools exist.

For the conceptual part, we critically screened the literature on both theories and their derivates, compared them to practical experiences and developed a new approach combining elements from both theories plus political economy and a heuristic making is applicable to strategy development (Spangenberg JH, Lorek S. 2019. Sufficiency and consumer behaviour: from theory to policy. Energy Policy 129: 1070-1079). This served as a background for the empirical part which consisted of collecting the widest possible range of sufficiency policy and strategy examples, regardless of their conceptual base (Lorek S, Spangenberg JH. 2019. Energy sufficiency through social innovation in housing. Energy Policy 126: 287-294). A bridging element between both parts is section 3, dedicated to the issue of developing narratives for sufficiency. It addresses the societal level (second bullet point) to change the discourse on energy consumption to make lower consumption socially desirable, a honoured achievement. This goes beyond technologies by including new forms of habitation, i.e. social innovations complementing technical innovations.

The method employed

The method employed for the conceptual part consisted of an intensive literature analysis regarding the role of different theoretical concepts underlying sustainable energy consumption strategies, and was extended to sustainable consumption in general as energy was often only one of several aspects covered. Analysing gaps and developing a new approach was conceptual desktop work.

Unfortunately sufficiency issues are hardly found in traditional EU reporting or data bases. The empirical part of the paper is therefore based on intensive literature review in journals which appeared to be potential sources of sufficiency literature, such as consumer/consumption, ecological economics, sustainability and other journals. In an initial google scholar search we identified over 50 journals relating to energy, sustainability or consumption issues to be screened. Based on the initial hits a more detailed search was conducted in 17 of them.

Papers mentioning “sufficiency” were analysed regarding the meaning they associated with the term (there is no consensus in the literature on how to use it so far, not least due to the different traditions of the diverse disciplines contributing) and selected those addressing the three bullet points mentioned above. They provide the cases discussed in this deliverable.

The data and sources

A rather general scan searching for the term “sufficiency” took place in 56 journals, with more detailed search (reading the abstracts to see if the issue had been addressed using a diverging terminology) in the 2015-2017 issues of 17 journals from consumer and sustainability research. Based on the abstracts, we classified the publications as either following – implicitly or explicitly – a line of thought similar to the three bullets mentioned above, or pursuing a different understanding of sufficiency.

For the papers identified as in line with our research interest, the full text was analysed and the examples provided used to populate the empirical part of this deliverable. Further information were taken from the emerging further literature, books or grey papers, on the issue.

The results

While in the majority of journals sufficiency does not appear at all, the few mentioning it tend to concentrate on self-sufficiency in a sense of voluntary simplicity. This is, however, not what this deliverable intends to analyse. Examples of sufficiency in a broader sense, incorporating the three bullet points mentioned, and not least the political context, were rare and are documented in this

Deliverable. In analysing them, we tried to identify the framing conditions which support sufficiency thinking and behaviour, beyond individual sacrifice.

Sufficiency considerations in such a sense were found in more hidden ways in various researches recognizing the limits of efficiency approaches (hence the need to analyse the abstracts in the journals mentioned) – mainly in energy, environment and housing related journals. The most concrete and developed ideas, however, still seem to be in a project phase and have not made its way to peer reviewed academic journals. Therefore in broad parts the deliverable is based on exemplary projects, mainly found in a German, Swedish and Swiss context. The selection of the final collection of ideas and instrument presented here were steered through exchange and interviews with scholars and practitioners working in the field of e.g. energy efficiency, energy consultancy and 'beyond GDP' research and initiatives.

One key driving force of domestic energy consumption turned out to be the size of flats or dwellings. Thus we focussed our analysis of potential tools to stimulate reductions in household energy consumption (defined as in earlier deliverables as the domestic consumption, excluding the energy spent out-of-house e.g. for mobility of food provisioning). Then the cases found were screened for innovative policy proposals stimulating small-space-high-quality living.

Their significance for policy-makers, stakeholder, and/or other researchers

Reducing the size of individual living space while upgrading its quality and life satisfaction provisioning function so far is a challenging task for design and architecture – not least because architects' payment in many countries is based on the built volume, not on the quality of the resulting buildings. From a tenants perspective however, smaller individual flats in combination with shared facilities such as laundry rooms or guest rooms on short additional rent and user-friendly smart technologies can make both environmental and economic sense. In particular in an ageing society with increasing numbers of single person households, flats bought or rented in earlier life phases and suitable at that time can become a burden to maintain later. While exchange platforms can help occasionally, moving to a distant place (often in the suburbs to compensate for the higher rent in new flats) tears social networks apart, besides the financial aspects another justified reason for elderly people to stay put. While technologies permitting for flat size adjustments are known since more than 40 years, they have rarely been used in construction, e.g. of social housing. Adjusting building codes accordingly to be better prepared for future changes in demand, and support programs for adjustments now could help improve quality of life for residents while creating additional housing opportunities in inner city regions.

On the other hand, in particular for younger residents, the driving force for lower floor space claims is often economic: because land prices are high and people want to live in cities where currently prices go through the roof in many countries, people either have to commute long distances at relatively high cost, or pay a fortune for a few square meters in urban centres. Thus quite some examples under development or carried out already show that downsizing is gaining popularity.

A further motivation for engaging in such projects – be it as individual, as planner, as landlord, or as municipality – is to learn more about the consequences of building smaller while obtaining sufficient, even improved quality of accommodation from such small areas. In turn, the attention such projects receive contributes to raising awareness of the underlying intention of sufficiency. Creative and structured communication processes can further help to build trust between planners, designers and architects, municipalities and politics, all other actors and the inhabitants, and this can stimulate efforts to overcome planning rigidities and bureaucratic obstacles.

D5.5. Identification of promising instruments and instrument mixes to promote energy sufficiency

Lorek, Sylvia and Spangenberg, Joachim H.

Executive summary

The issue to be explored

Sufficiency or enoughness is a normative approach postulating upper and lower limits of consumption, for environmental and for social reasons. It is addressing the general sociotechnical environment of energy use on three different levels of decision making (from D5.3):

- policies are called upon to set suitable framework conditions and mechanisms guarantying both sufficient energy supply to lead a decent life in the respective society, and limitations of energy consumption in line with environmental concerns and obligations (like the Paris Accord);
- society is urged to adapt preferences, value systems and orientations which are produced and reproduced in the interaction of individuals, peer groups and the wider social environment; and
- individuals are encouraged to change their behavioural practices, intervening in societal discourses and value developments, and change their behaviour as far as it has been squandering resources/energy and can be done on the prevailing material and social settings. Voluntary simplicity can play a limited role on this level.

Whereas the second and third aspects predominantly address collective and individual behavioural change and thus mostly the upper limit of permissible energy consumption under environmental constraints and a measure of equality in the distribution of energy use potentials, the first one clearly requires measures against energy deficiencies as much as those against energy overconsumption and squandering. One example in the literature is combining a free basic energy supply with progressive pricing of energy consumption to address both the upper and the lower boundary conditions. Sufficiency is not lauding poverty, but attempting to overcome it, in energy and other terms.

The most prominent example of setting upper limits so far are the 'Planetary Boundaries', while the lower limit, the floor of the environmental space or – in Latin America – the Linea de Dignidad, has been operationalised by the 'Social Protection Floor' endorsed by the 2012 Rio de Janeiro UNCSD conference. Thus international policy objectives are available for both kinds of limits, and for the lower one also enshrined in the SDGs. But while there is a wealth of policy instruments addressing different aspects of poverty (which are often, of course, in need to be fixed and improved to deliver on their targets), there is a dearth of policy instruments limiting individual consumption (apart from consumption taxes with potentially regressive effects). This is why this WP focusses on the upper limit and looks for instruments how to limit overconsumption, exemplified by means how to reduce the living space per flat as a main driver of household energy consumption.

While other Work Packages of the project deal with what business or industry can do to reduce energy consumption, WP 5 is dedicated to the agency of households and consumers as the dominant sector of final demand, and more specifically on domestic consumption. In domestic energy use (i.e. excluding out-of-house energy consumption, e.g. for mobility), by far the largest amount of energy is used for low temperature heat for room heating and hot water provision, and a smaller share of 10-

15% for electricity running household appliances. Use patterns and efficiency options have been described in WP 5.2 and its summary.

What was done to investigate it

As sufficiency is an emerging field both in academic research and in public discourses, we aimed at gathering a comprehensive overview over both fields. Information about the academic debates was gathered by organising expert workshops on behalf of the project, which allowed for access to not yet published projects and research efforts.

In an action research approach, we also participated in a series of workshops and conferences hosted by civil society and academic institutions, presented the WP 5 research results and collected feedback which was used to refine the final versions of the Deliverables.

The method employed

The identification of policies and policy mixes presented in this paper was carried out in a combination of desktop research, policy analysis and action research (as described above). The literature analysis was based on the findings from D5.3 and the policy analysis followed the method described there.

In the action research, the results from the stocktaking (D 5.3) were presented, discussed and further developed at the following events organised by EUFORIE and bringing together expert groups in different parts of Europe (Germany, UK, Spain, and Finland).

- EUFORIE Expert workshop on sufficiency, in collaboration with BUND (Friends of the Earth Germany), Frankfurt, July 2017
- EUFORIE workshop at the Festival of New Economic Thinking , Edinburgh, October 2017
- EUFORIE advisory board meeting, Barcelona, April 2018
- Workshop at the EUFORIE Final Conference 'Energizing Futures', Tampere, June 2018
- 6th International Degrowth Conference 'Dialogues in turbulent times', Malmö, August 2018 (several workshops and presentations)
- EUFORIE Roundtable discussion 'From physics to policy: Overcoming misperceptions in energy policy', Brussels, September 2018

During all meetings, workshops etc. notes were taken, with particular care regarding the feedback to the project presentations, but also regarding the diverse definitions and applications of the sufficiency concept in general. These notes were discussed by the team regarding their relevance for the further development of the Deliverables, and the results integrated into the Deliverable text.

In this way, all these events contributed in one form or another to the specification of the findings and recommendation given in this deliverable by providing feedback to preliminary results, stimulating refinements of the research questions and pointing to additional references and materials.

The data and sources

As described above, the sources were the diverse events the team members participated in, and the notes taken from the discussions. For conferences where expert agents other than the team members (academics, civil society experts, practitioners) gave presentations, these were collected and included into the analysis of the event results and their relevance to the project.

The data used were the result of the literature analysis described in D5.3, and the analysis of the event results, whether specifically as feedback to EUFORIUE presentations or more general talks on the sufficiency concept.

The results

Based on the concept of enoughness, sufficiency at a lower end means overcoming energy poverty. In the case of financial poverty leading to insufficient purchasing power to afford a suitable level of energy consumption, financial transfers are a well-established (although not necessarily effectively applied) policy tool. In the case of involuntary energy squandering due to habitation characteristics, public support for energetic modernisation is a (often necessary) condition for achieving acceptable comfort standards without overburdening household budgets. Programs for this behalf are available in many EU member states; they have been established as energy efficiency programs and are thus described in Deliverable D5.2.

As opposed to the lower end, there are hardly any established policies addressing enoughness at the upper end, i.e. for setting limits to individual or household energy consumption. This is a pity as sufficiency policies, besides skimming off the rebound effects of efficiency policies, can provide a cost-effective means of reducing greenhouse gas emissions, thus contributing to the European climate policy targets and the achievements set by the Paris Accord. Only within sufficiency limits the well-established energy efficiency technologies and instruments can develop their full potential. Sufficiency policies are therefore a necessary condition to make efficiency effective.

A key area highly contributing to domestic energy consumption – and thus in need for sufficiency – is low temperature heat for warming the habitation and for warm water provisioning (a minor share). So far underrepresented in the public debate is the constantly increasing dwelling area per person as a key driver of domestic energy consumption. It not only determines the area which needs to be heated or cooled but also provides space for additional appliances, often electricity consuming ones. The focus of this deliverable has therefor been chosen to be potential instruments for sufficiency oriented size of sustainable homes. While of course not the only determinant, this is a key factor neglected so far and is used to exemplify the new approach under sufficiency thinking, and the obstacles still hampering its application.

The EUFORIE project and the broader sufficiency debate have been fertilizing each other not at least through the regular exchanges in the ENOUGH network - International Network for Sufficiency Research and Policy.

Their significance for policy-makers, stakeholder, and/or other researchers

To factually develop towards shrinking and not further increasing individual floor space, various policy measures need to be established in parallel. Most relevant are to rethink building regulation actually hindering sufficiency developments, limiting further soil sealing in favour of better and more sufficient use of the existing building stock, shifting to a progressive property tax, establishing sufficiency criteria for public loans and – last but not least – set up sufficiency consultancy based at the municipality level.

While social and environmental science provide clear orientation for adequate upper and lower levels it seems necessary to work towards societal debate and factual change. To overcome the restricted perspective that sufficiency is a purely individual decision the deliverable proposes policies for the different levels of governance. They rank from adjusting requirements for minimum dwelling size and caps for further soil sealing on the national or even EU level to the establishment of sufficiency consultancy on the local level. Such policies need to be embedded in activities at a societal level where NGOs raise awareness for the issue and housing companies in collaboration with architects and urban planners develop-- creative ideas where sufficient lifestyles can flourish in sufficient neighborhoods.

Collecting the (few) available examples the deliverable intends to stimulate a discussion (a) on potential policy instruments and target values for habitat sizes, and (b) more general to illustrate the new perspective on policy measures emerging from a sufficiency view point. This is not least of political interest as sufficiency approaches may provide cost-effective complements to the well-established energy efficiency strategies.

WP6 deliverables: Microeconomic efficiency analysis of selected case study companies and sectors

D6.1. Report on ASA analyses of energy efficiency at company level

Vehmas, Jarmo and Ameziane, Maria

Executive summary

Task

The purpose of this deliverable is to study how energy efficiency has affected energy consumption, raw material consumption and environmental impacts at the company level. For this purpose, five case companies were selected by using the following criteria: (1) energy as a major production factor, and/or (2) energy as a major product, and (3) good availability of data from public sources (annual reports, environmental reports, sustainability reports, corporate social responsibility reports, websites, and databases. The selected companies include energy companies ENEL (Italy), RWE (Germany) and CNPC (China), and industrial companies Stora Enso (pulp and paper, Finland/Sweden) and Celsa Barcelona (metal products, Catalonia/Spain).

Method

A chained two-factor decomposition analysis was used to carry out the research task. Several different analyses were made depending on the availability of data of different indicators at different levels in the case companies. Selecting different indicators for analysis offers an opportunity to receive a wide perspective to a company's performance in terms of energy efficiency, material efficiency and environmental efficiency.

Data

Publicly available data from the case companies was used in the analyses. The selected data describes the performance of the company:

- the amount of production (total production and selected products/product groups in physical units)
- energy consumption (consumption of total energy and different energy carriers)
- raw material use (selected major raw materials), and
- environmental impacts represented by emissions into air such as CO_2, SO_2, NO_x emissions, and amount of waste.

The availability of time series data (required by the decomposition analysis) at different levels inside a company was very different in different case companies. The time period analysed covers the years from 2010 onwards in all case companies.

Results

Several different decomposition analyses were carried out for all case companies. The results show that energy intensity, material intensity, or environmental intensity has in many cases decreased in the industrial and energy companies selected for this study. Many of the decomposition analyses show decreasing effects − sometimes very significant ones − to energy and material consumption, and especially to environmental impacts. Sometimes the decreased intensities have only been able to slow down the increase of energy and material consumption and environmental impact caused by the increasing amount of production. As a conclusion, at the company level, the most important driver of energy consumption, raw material consumption and environmental impacts, is the amount of production. It explains a vast majority of observed absolute changes in energy and raw material consumption and in environmental impacts – both decreases and increases.

The study also brought out several improvement possibilities to company reporting regarding the data describing their operational performance. Time series data on environmental indicators (such as emissions into air, water and soil, and waste), the use of different primary energy sources and different energy carriers, the use of major raw materials, and the amount of production (in both physical and monetary units) would enable a proper decomposition analysis of company performance. Even more beneficial could be if the data would be available also for individual production sites, for different production processes, or even for individual products.

Use of the results

The results are useful for industry, and especially for the selected case companies. The results may benefit all companies interested in improving their external communication via publicly available reports as well as databases and data management tools. The methodological approach is useful of researchers in the fields of environmental management and environmental policy. The results offer an insight at the company level also for policy makers in the EU and in individual Member States.

D6.2. Report of energy efficiency at company level

Vehmas, Jarmo

Executive summary

Task

The purpose of this deliverable is to develop and test new efficiency indicators for companies. The indicators should describe change in energy, material and environmental efficiency better than the commonly used specific consumptions and specific emissions (calculated per unit of production) do from the sustainability point of view. The indicators should give more information about the company's energy, material and environmental performance than the existing indicators.

Method

The task of indicator developing is done by refining results from a two-factor decomposition of energy use, material use, and environmental output. The results, activity and intensity effects, can be calculated by a preferred decomposition technique. From the activity and intensity effects, it is possible to calculate

1. how much the activity effect can change without an increase in energy use, material use, or harmful environmental outputs, and
2. how much the intensity effect needs to change from the original value, that energy use, material use, or harmful output to the environment will not increase.

By doing this the possible rebound effect will be taken into consideration, which is important from the sustainability point of view. As a result, two new indicators will be introduced: sustainable growth (SG) and sustainable intensity (SI). They can be calculated as follows:

$$SG = -\frac{Intensity\ effect}{Activity\ effect} \times 100\ \%$$

$$SI = -\frac{Activity\ effect}{Intensity\ effect} \times \frac{V_0}{V_t}$$

where V_0 is the original value and V_t the changed value of the selected indicator describing energy use, material use, or environmental output during the studied time period. SG shows the "sustainable" part as percentage from the observed activity change. SI is a coefficient: multiplying the observed intensity effect with the SI coefficient tells the "sustainable" intensity effect. A good thing in these new indicators is that they are applicable at any level of economic activity, and the variables to be included in the analysis can be chosen by the user. A causal relationship between the chosen variables is expected and assumed. Typical examples of an assumed causal relationship include:

- production explains energy use
- production explains material use
- production explains environmental output
- energy use explains environmental output
- material use explains environmental output.

The indicators SG and SI have also their weaknesses and challenges of interpretation. They are not stand-alone indicators, because similar values may be a result from different situations. Details for this can be found in this deliverable.

The task of testing the new indicators is done by calculating the SG and SI indicator values for selected case companies by using different combinations of publicly available data from the company websites, open databases, and environmental and other company reports. The case companies include three energy companies: ENEL (Italy), RWE (Germany) and CNPC (China), and two industrial companies: Stora Enso (pulp and paper, Finland/Sweden) and Celsa Barcelona (metal products, Catalonia/Spain). Several tests for each company have been done. In the tests, activity is measured by the amount of production, but in some tests also by energy or raw material use. Intensity is measured by dividing energy or material use, or environmental output by the activity variables.

Data

The tests are done by using the various possibilities offered by the selected data used in D6.1. The analysis covers the years from 2010 to the most recent year with the publicly available data from the case companies.

Results

Based on the tests, the production/economic activity of the European companies has not always increased. Often it has decreased, especially in terms of annual changes. Decreasing production (activity effect) has usually decreased also energy use, material use and environmental output more than the intensity effect has changed them. In the light of the SG and SI indicators, performance of the companies, especially the industrial companies Stora Enso and Celsa Barcelona, is determined by the changing activity. Another observation is that during the relatively short period analysed (2010-2016), the intensity effect does not usually play a major role in decreasing energy use, material use, or environmental impact.

This study brought out additional improvement possibilities to company reporting. Regarding the operational performance from the sustainability point of view, the indicators SG and SI could provide additional information. The results are useful for companies, especially to those willing to improve environmental and sustainability reporting. The developed indicators SG and SI are applicable to any system, so there are options available to apply them also elsewhere than in companies. The results may be of interest also to policy makers in the EU and individual Member States, for NGOs and all stakeholders interested in energy, material and environmental performance of economic systems and organisations. The developed indicators are first versions and have their weaknesses, but they offer also a starting point for further improvements done by sustainability-oriented researchers.

WP7 deliverables: Participatory energy efficiency foresight analyses for the European energy efficiency vision and strategy

D7.1. Summary report of the participatory national EUFORIE workshops

Vehmas, Jarmo, Ulgiati, Sergio, Giampietro, Mario, Lorek, Sylvia, Ameziane, Maria, Vassillo, Chiara, Velasco-Fernández, Raúl, Ripa, Maddalena, Bukkens, Sandra and Spangenberg, Joachim

Executive summary

Task

The purpose of this deliverable is to present the views on energy efficiency and its role in energy and environmental policies based on the opinions of different stakeholder groups.

Method

For this, a set of national workshops was arranged in the Euforie project, where selected results of the project were presented and discussed. Three workshops were organised altogether, the first one in Rome, Italy in November 2016, the second ne in Barcelona, Spain in March 2017 and the third one in Frankfurt A.M. in Germany in June 2017. Additional material was collected with two surveys in the context of the Italian and Spanish workshops, and with stakeholder interviews carried out in Finland in May-June 2017.

Title of the workshop	International workshop on costs and benefits of energy efficiency – Scenarios for Italy and Europe	Lessons learned from a critical analysis of European energy directives: Policy implications for Pla de l'Energia i Canvi Climàtic de Catalunya 2012-2020	Beyond energy efficiency
Location	Rome, Italy	Barcelona, Catalonia/Spain	Frankfurt a.M., Germany
Date	18.11.201	24.3.2017	2..6.2017
Number of participants	32	43	26
Survey on energy efficiency	Yes	Yes	No
Responsible EUFORIE partner	Parthenope University of Naples, Italy	Autonomous University of Barcelona, Spain	Sustainable Europe Research Institute, SERI Germany
Notes	In collaboration with the Federation of energy service companies (FEDERESCO)	In collaboration with Associació i Col·legi d'Enginyers Industrials de Catalunya (CEIC)	In collaboration with Bund für Umwelt und Naturschutz (Friends of the Earth Germany)

Results

Energy efficiency is a popular catchword, but as a concept it is a relative one and its operationalization is strongly dependent on the context where the concept is applied. From a scientific point of view, the difficulty of operationalization goes hand in hand with the level of aggregation. At the macro level of society (national level), where policy targets are usually set, operationalization is almost impossible.

There is also overlapping between different fields of policies, where energy efficiency is a topic: In energy policy, energy efficiency has been promoted over 40 years for economic reasons. In environmental and climate policies, energy efficiency has been seen as a means to limit CO_2 emissions and environmental impacts in general – but this is seriously threatened by the Jevons paradox, which says simply that saved energy will be consumed elsewhere. In economic and employment policies, attention has been paid to an energy efficiency (service) market, motivated by potential job creation and economic growth. These issues make energy efficiency unclear as a policy target.

Absolute targets to reduce energy consumption (and related environmental impacts) from a measured level are better than relative targets or targets set in relation to a projected absolute consumption in the future (as the current EU target). Targets should be set at a level where monitoring is possible.

Indicators of energy efficiency, such as energy intensity, should be calculated by preferring the use of physical variables. Mixing physical and economic variables is problematic. Economic growth usually seems to decrease energy intensity, even though there is no real improvement in energy efficiency, but other things such as structural change or financial transactions instead.

Different policy instruments promoting energy efficiency may be useful in driving and supporting technological change and change in consumer behavior and lifestyle, which are important elements in reaching targets set on energy consumption or on related environmental impacts. There are many promising policy instruments, but what is needed is a monitoring system where the costs, benefits, and other effects of the use of the policy instruments in different EU Member States would be collected on a regular basis. However, there is no ultimate policy instrument, and the opinions on them vary a lot between different EU Member States and between different stakeholders.

Technologies for improving energy efficiency are available, for energy production and consumption, but the major problem seems to be that energy efficient technologies are not taken into use for economic reasons – usually payback periods are too long. It seems that the best drivers for energy efficiency are higher energy prices, and government policies are needed especially in cases where energy prices remain at a low level.

Use of the results

The results are useful for policy makers in the European Union and in the EU Member States, They are also of interest to all other stakeholders interested in energy and environmental policies, and especially in the role of the concept of energy efficiency in related target setting and design of policy instruments.

D7.2. Report of the roundtable results: Foresight analyses of European energy efficiency vision and strategy

Vehmas, Jarmo

Executive summary

Task, method and data

This report provides the results from the roundtable dealing with the most important and policy relevant results from the EUFORIE project. The roundtable discussion was held on 27th of September 2018 as a back to-back event after the European Modeling Platform for Energy (EMP-E) conference in Brussels, Belgium. This report includes the results from the roundtable discussion after four presentations on mostly methodological aspects of energy, material, and environmental performance analysis of different systems, from households and companies to EU Member States and the Community as a whole.

Results

The original target of the roundtable discussion was to find a “common sense” how the energy efficiency could be approached and enhanced in a best possible way in preparation of a European vision and strategy on energy efficiency. During the implementation of the project it become clear for the EUFORIE consortium that a proper performance analysis regarding energy and material use, as well as related environmental impacts at different levels in the EU and its Member States is needed first. Then the next step includes targets, policies and measures for promoting energy efficiency. Thus, the most important outcome of the EUFORIE project is a set of methods that enable a proper energy, material and environmental performance analysis. Several examples of these analyses have been already done in the EUFORIE project, but the analysis needs to be continued, especially in the EU Member States.

The roundtable discussion did not challenge the initial assumption of the EUFORIE project that without better analysis of energy, material and environmental performance, there is a serious risk of false choices in setting policy targets and activities for implementing them such as policy measures. The methods developed and applied in the EUFORIE project were seen as potential ones for a better performance analysis at different levels, but the challenge to communicate them and the results effectively to policy planning in the EU and in the Member States remains as a major challenge. In addition, the roundtable discussion provided the EUFORIE project important ideas and challenges to take into account in further activities. For example, a possibility to use open data in LCA is an interesting option, s integrating bio-physical and economic energy modelling approaches. An important issue not directly dealt with in the EUFORIE project is the social dimension of the performance analysis, which hopefully, will be included and highlighted in the next EU framework programme under construction, called as “Horizon Europe”.

Use of the results

The results are useful for policy makers in the European Union and in the EU Member States, and they are of interest to all stakeholders including researchers, NGOs and energy industry and companies who are interested in energy and environmental policies and the role of the concept of energy efficiency in it.

WP8 deliverables: Chinese energy efficiency and comparison of European/Chinese policy effectiveness

D8.1. Energy Efficiency Policies and Measures in China

Vehmas, Jarmo and Chen, Ying

Executive summary

Task

Energy use, especially the use of coal, and related environmental impacts are huge in China, and the related trends are rapidly increasing because of continuous industrialisation, urbanisation, and economic growth among the fastest in the World. From the year 2000 onwards, average annual economic growth has been around 10 % in China, and the construction and industrial sectors have grown faster than the whole economy. China is nowadays the largest coal user and emitter of greenhouse gases in the World. Acid rain due to SO_2 and NO_x emissions from coal-fired energy production and poor urban air quality caused by particulate matter (PM) emissions from vehicles and local burning of coal are serious problems as well. China is also an oil exporter, so in addition to negative environmental impacts of energy use, also energy security is a reason for improving energy efficiency in China.

The purpose of this deliverable is to give an overview of the drivers and policies of energy efficiency in China, to look at how energy efficiency has affected energy use and related CO_2 emissions, and to construct scenarios about the possibility to reach the most recent Chinese policy targets introduced in the 13th FYP. The focus is on national scale, but quantitative analyses of sectoral and provincial level energy efficiency has been done in other EUFORIE deliverables.

Method

The method used for Chinese energy efficiency drivers and policies includes literature review including a detailed analysis of recent Chinese five-year plans (FYP), China's intended nationally determined contributions (INDCs), and three most recent documents about China's policies and actions for addressing climate change, published by the National development and Reform Commission (NDRC). The impact of energy efficiency on energy use and CO_2 emissions is analysed by incremental chained two-factor decomposition analysis, which calculates the effect of change in energy efficiency related drivers (energy intensity and the primary/final energy use ratio) and other drivers to the change of energy use and CO_2 emissions. In addition, a baseline scenario and two different energy efficiency scenarios, a policy scenario and an enhanced policy scenario are constructed by using the LINDA (long-range integrated development) modeling approach. The scenarios are results of different assumptions on economic growth and fuel and electricity intensities in the different economic sectors in China, given by Chinese researchers.

Data

The used quantitative data includes historical CO_2 emissions from fuel combustion, total primary energy supply, final energy consumption, GDP in real prices and population taken from International

Energy Agency (IEA), and sectoral data and fuel and electricity data used in the ChinaLinda model is taken from the Chinese National Bureau of Statistics.

Results

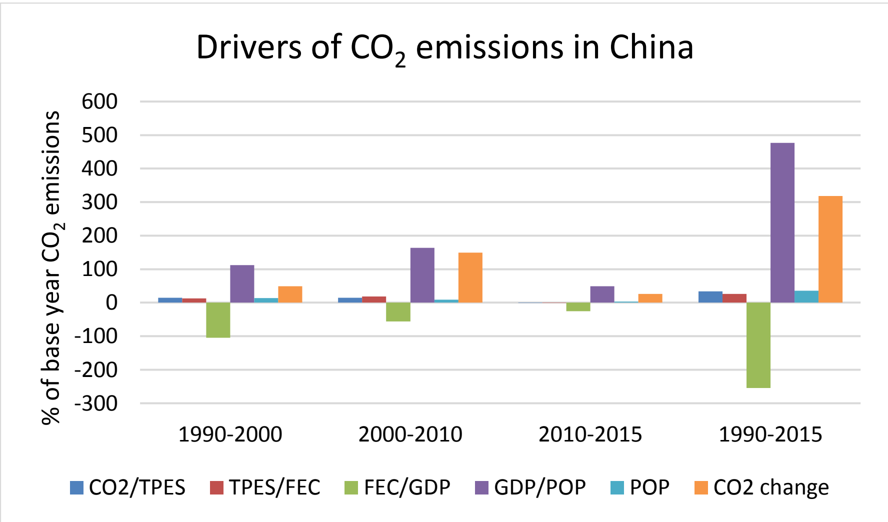
Results of the analysis show that in the five-year plans (FYP), the Chinese Government has introduced many policies and measures in order to improve energy efficiency, and the policies include many specified targets for different activities of the economy. At the national level, in the 11th FYP, quantitative targets were set for the first time for CO_2 emissions per unit of GDP, and for the share of renewable sources in the energy mix, for example. Since then, more enhanced targets have been set in the 12th FYP and the current 13th FYP for the years 2016-2020 (see the table below).

Targets related to energy efficiency for the years 2016-2020 in the 13th FYP of China.

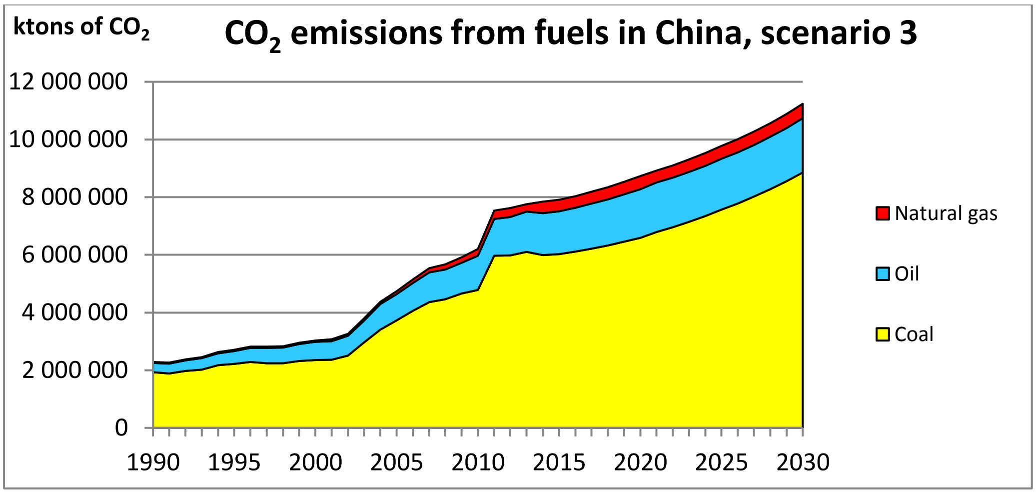
Energy consumption, reduction per unit of GDP (%)	15
Non-fossil energy (% of primary energy consumption)	3
CO_2 emissions reduction per unit of GDP (%)	18

The analysed policy documents list a very large number of detailed new policies and measures to ensure that the introduced targets will be met. Many of them are traditional command and control mechanisms, but on the other hand, a national emissions trading scheme for greenhouse gas emissions was launched in December 2017.

Effectiveness of the Chinese energy efficiency policies can be assumed from the decomposition results, because there is a rapid decrease in energy intensity of the Chinese economy, although the industrial sector has grown at a fast rate (see the figure below). Fast economic growth and the coal-dominated energy mix have increased CO_2 emissions, and only the speed of increase has slowed down by the decreased energy intensity. Population growth has also slightly increased energy use and CO_2 emissions in the long term.



The major conclusion from the analysed policy documents is that China usually reaches the relative targets set in the FYPs, and sometimes exceeds them. It is beyond this deliverable to find out is it easier to set targets realistic enough, or to meet ambitious targets with an effective control system available. The historical results are reflected also in the constructed scenarios. In the enhanced policy scenario (see the figure below), the increase of CO_2 emissions continues, because economic growth is close to the 13th FYP and decreased fuel and electricity intensities only slow down the increasing use of coal in China.



Use of the results

The results of this deliverable are useful for all interested in Chinese energy and climate policies, and for those who want to get an overview of China's performance in terms of energy use and CO_2 emissions. The methods used in the analysis, chained two-factor decomposition analysis and the Linda modeling approach are of interest to the researchers in the field of energy and sustainability research. The EUFORIE project has also done comparisons between China and the EU, which are available for further information.

D8.2. Impacts of Main Economic Sectors on Energy Efficiency in the period 2015–2030 in China

Chen, Ying, Jiang, Jinxing, Panula-Ontto, Juha and Vehmas, Jarmo

Executive summary

Task

The purpose of this deliverable is to get an understanding of the energy efficiency development in China in relation to the official targets and to measure the improvement in energy efficiency performance of the different economic sectors in China.

Method

This has been done by first decomposing the final energy consumption into an activity, intensity and structural effects at two different levels of aggregation. The used decomposition method is the Sun-Shapley method, which provides a perfect decomposition by allocating the residual to the three effects under the principle “jointly created, equally distributed”.

From the decomposition results, the sectoral intensity effects have been used as input in the ChinaLINDA model. The modelling is used for constructing a future projection of a possible development of energy use and carbon dioxide (CO_2) emissions in China, a baseline scenario. This scenario is compared to another projection, where the aspired energy efficiency targets of the Chinese 13th five-year plan are reached.

The ChinaLINDA model used is based on an extended Kaya identity, and it includes different economic sectors and mixes of primary energy sources and different energy carriers:

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP$$

Data

The decomposition analysis of final energy consumption of the Chinese economy uses data from National Bureau of Statistics of China and the World Input-Output Database. The sectoral final energy consumption data has been extracted from the National Bureau of Statistics of China database. The sectoral value added data is sourced from the World Input-Output Database. The other data used in the ChinaLINDA model, including primary energy data, economic data and population data, is taken from the National Bureau of Statistics database.

Results

The analysis of energy intensity development in China shows the following results. Manufacture of motor vehicles, trailers and semi-trailers, manufacture of food, beverages and tobacco products, mining and quarrying, manufacture of coke and refined petroleum products, and manufacture of other non-metallic mineral products are the most interesting economic sectors in terms of a good performance and development towards a less energy intensive production in the future. On the other hand, the printing and reproduction of recorded media, the transport sector, the manufacture of rubber and plastic products, and the manufacturing of furniture and wood products show a negative

development or a relatively slow positive development in terms of energy intensity, hinting at a possible energy savings potential within the activities carried out in these sectors.

The mining sector has overall contributed the most significantly to energy savings through energy efficiency improvements, and nearly as important is the manufacture of non-metallic mineral products sector. A third very significant sector in terms of absolute energy savings through efficiency gains is the manufacture of coke and refined petroleum products sector. Problematic sectors with large quantity effects but negative energy efficiency development are especially the manufacture of basic metals sector and the transport sector. Poor efficiency development and high volume of economic activity in these sectors hint at a significant potential for efficiency gains that might possibly be achieved by well focused policy interventions.

The Chinese policy targets for energy efficiency appear to be stringent in the light of observed development in energy efficiency. However, if the energy efficiency policies are successfully implemented and the aspired energy intensity goals are met, the energy saved and the avoided CO_2 emissions are decisively lower than in the business-as-usual case of continuing the development along the observed trend of energy intensity in China. The tables below show the differences in CO_2 emission development in these two scenarios:

Projection of CO_2 emissions and final energy consumption (FEC) under the policy scenario:

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CO2 (Mtons)	8401	8630	8873	9131	9353	9557	9780	10023	10287	10506	10752	11026	11329	11662
FEC (Mtoe)	2594	2629	2667	2709	2741	2736	2736	2743	2756	2735	2724	2723	2731	2750

Projection of CO_2 emissions and final energy consumption (FEC) under the trend continuation scenario:

	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
CO2 (Mtons)	9037	9499	9987	10502	11026	11521	12042	12588	13161	13683	14230	14803	15404	16032
FEC (Mtoe)	2970	3143	3327	3523	3693	3862	4039	4226	4423	4585	4754	4932	5119	5316

Use of the results

The results and analysis of this deliverable are useful for the researchers in the field and other stakeholder groups interested in Chinese energy performance and energy policies. The analysis and results are especially useful for the researchers and interest groups interested in decomposition analysis of energy and CO_2 emissions, and constructing alternative future scenarios for China.

D8.3. Chinese residential sector analysis

Chen, Ying, Jiang, Jinxing, Panula-Ontto, Juha and Vehmas, Jarmo

Executive summary

Task

The EUFORIE WP8 analyses energy efficiency in China at different levels: the macro level, the sectoral level, the provincial level, and the company level. The purpose of this deliverable is to deepen the sectoral level analysis presented in deliverable D8.2 to get an analysis of a selected sector; how changes in energy efficiency and change in different trends affect energy consumption and carbon dioxide emissions of the selected sector. The selected sector is the residential sector, which includes energy consumption in households. The residential sector is one of the fastest growing sectors in terms of energy consumption in China in the future.

From the starting point described above, this deliverable looks at energy efficiency development in the residential sector in China. The focus is in how changes in urbanization and the amount of population have an effect to energy consumption and related carbon dioxide (CO_2) emissions in the residential sector in China.

Method

This task will be done by using the ChinaLINDA model, which is constructed in the EUFORIE project for constructing scenarios for the macro and sectoral levels. ChinaLINDA is based on data accounting, and it relies on an extended Kaya identity which identifies the drivers of CO_2 emissions from fuel combustion:

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP$$

where TPES is total primary energy supply, FEC is final energy consumption, GDP is gross domestic product or vale added in constant process, and POP is the amount of population. The drivers include changes in carbon intensity of the primary energy mix (CO2/TPES), the TPES/FEC ratio (which is a proxy for efficiency of the entire energy transformation system), energy intensity of the economy (FEC/GDP), economic growth per capita (GDP/POP) and the amount of population (POP). Each of these drivers may increase or decrease CO_2 emissions in the selected time period.

The ChinaLINDA model represents the Chinese energy system incorporating different economic sectors, including the residential sector and the construction sector, into the model. Furthermore, the model includes the mix of primary energy sources for the production of energy carriers, and the mix of energy carriers in the final energy consumption of different sectors. The model uses changes in economic activity as well as fuel and electricity intensities as the major input given by the model user. Therefore, the ChinaLINDA model can be used for providing projections on the impact of different assumptions, including assumptions on population growth and urbanization rate, on energy use and CO_2 emissions in China, and on the impact of different levels of assumed energy efficiency improvements, presented in terms of fuel and electricity intensities.

Data

The data of final energy consumption of the Chinese economy uses data from National Bureau of Statistics of China and the World Input-Output Database. The sectoral final energy consumption data has been extracted from the National Bureau of Statistics of China database. The sectoral value added data is sourced from the World Input-Output Database. The other data used in the ChinaLINDA model, including primary energy data, economic data and population data, is taken from the National Bureau of Statistics of China database.

Results

The temporal horizon selected for the analysis is until the year 2030. The use of ChinaLINDA model in examining energy efficiency developments in the residential and construction sectors in China revolves around varying the assumptions on population growth, urbanization speed and rate of energy efficiency improvements in the urban and rural areas. From different combinations of these scenario pivot points, different scenario configurations can be formed. The baseline development follows the targets set in the 13th five-year plan for China.

This report presents a ChinaLINDA model driven scenario study of the effects of different sub-scenarios regarding the Chinese urbanization process as well as residential and construction sector energy efficiency development on final energy consumption, electricity consumption and CO_2 emission levels. Fast urbanization, more ambitious energy efficiency policy in the use of buildings, and being able to make at least some energy efficiency gains in the construction sector would result, according to the ChinaLINDA projection, significant reductions by the year 2030:

- 172 Mtoe in final energy consumption
- 40 Mtoe reduction in electricity consumption-
- 300 Mton reduction in CO_2 emissions in 2030

The reductions are in comparison to the baseline scenario where a slower urbanization process, slower residential sector energy efficiency development and slow energy efficiency development in construction sector is assumed.

Use of the results

The results are useful for all stakeholder groups (policy makers, researchers, NGOS and citizens, and energy industry/companies interested in the residential sector development in China, especially for those researchers who consider focus on the impact of population, urbanization and energy efficiency on the fuel and electricity consumption and CO_2 emissions in China as important issues.

D8.4. Provincial energy efficiency analysis in China

Vehmas, Jarmo and Alexeeva, Anna

Executive summary

Task

The purpose of this deliverable is to analyse energy efficiency in China at the provincial level. The goal is to find out how the energy efficiency related drivers have affected energy use and related carbon dioxide emissions in different Chinese provinces and other administrative regions.

Method

To reach the goal, an incremental chained two-factor decomposition analysis has been carried out for analyzing the effects of change in indicators of energy efficiency and other drivers of total primary energy supply (TPES) and carbon dioxide emissions, identified in extended Kaya type identities, from fuel combustion (CO_2) in 20 Chinese provinces and other administrative regions.

$$TPES = \frac{TPES}{FEC} \times \frac{FEC}{GRP} \times \frac{GRP}{EMP} \times \frac{EMP}{POP} POP$$

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GRP} \times \frac{GRP}{EMP} \times \frac{EMP}{POP} \times POP$$

where TPES is total primary energy use, FEC is final energy consumption, GRP is gross regional product in constant/real process, EMP is the amount of employed persons and POP is the amount of population.

Four selected regions (Guangdong, Hebei, Shandong and Tianjin) with different profiles in terms of CO_2 emissions, economic structure and urban/rural population have been looked at in more detail to interpret the decomposition results.

Data

The data has been gathered from Chinese national energy statistics provided by the National Bureau of Statistics (NBS) and regional statistical yearbooks provided by the regional administration. The collected data includes annual CO_2 emissions, total primary energy use, final energy consumption, gross regional product (GRP) and amount of population from the years 2005-2014. The regional statistics are available mostly in Chinese, so this deliverable includes a description about data availability and problems of data collection and interpretation of Chinese statistics (see Annex 1).

Results

The most important driver of TPES and CO_2 emissions with a decreasing effect in the period 2005-2014 has been “energy intensity” (FEC/GRP), which has decreased TPES and CO_2 emissions in all administrative regions in China, except the Xinjiang autonomous region. The driver “carbon intensity” (CO_2/TPES) has increased CO_2 emissions in the provinces of Anhui, Guangdong, Jilin, Shaanxi and Shandong, and in the autonomous regions of Inner Mongolia and Xinjiang. In the other 13 Chinese administrative regions, the driver CO_2/TPES has decreased CO_2 emissions.

The driver (TPES/FEC), the ratio between primary and final energy use, describes efficiency of energy production, transfer, and distribution – the smaller the ratio, the better the efficiency. Usefulness of the TPES/FEC ratio suffers from statistical practices of measuring some energy sources in terms of primary energy, such as wind, solar, geothermal and nuclear. However, from the point of view of decomposition analysis, this driver, "efficiency of the energy transformation system", is relevant because it describes change in the primary energy mix and change in the efficiency of energy production. The driver TPES/FEC has had a relatively small effect to total primary energy supply (TPES) and carbon dioxide emissions from fuel combustion (CO_2) in almost all Chinese regions. A decreasing effect to both TPES and CO_2 in the province of Shaanxi, and an increasing effect to both TPES and CO_2 in the province of Shanxi can be mentioned.

The driver "energy intensity" (FEC /GRP) has had an increasing effect to both total primary energy use and CO_2 emissions in all provinces. A decreasing effect of this driver is a surprise in Chinese provinces and other administrative regions. There is a couple of annual decreasing effects in the results for the province of Shanxi and the autonomous region Inner Mongolia during the studied period 2004-2014, they are for both total primary energy use and CO_2 emissions.

The drivers "labour productivity" (GRP/EMP), "employment" (EMP/POP) and "population" have usually increased both TPES and CO_2 in all the studied Chinese provinces and other administrative regions. GRP/EMP has been the most important driver with an increasing effect to TPES and CO_2.

A major finding is that despite of a significant decreasing effect of energy efficiency (decreasing energy intensity), total primary energy supply and CO_2 emissions have increased in most of the Chinese regions because other drivers such as economic growth has had a larger increasing effect. However, the rate of increasing has been lower in the recent years, especially in urban regions such as the municipalities of Beijing and Tianjin.

The results of decomposition analysis of total primary energy use and CO_2 emissions in the 20 Chinese provinces and other administrative regions are presented as Figures for the period 2005-2014 in the second chapter "Decomposition analysis of total primary energy supply and CO_2 emissions in China at the regional level" of this deliverable. Detailed annual results are available for total primary energy use in Annex 2 and for CO_2 emissions in Annex 3 of this deliverable.

Use of the results

The results show that the differences between Chinese provinces and other administrative regions are large in a similar way than the differences between EU Member states. The results from the decomposition analyses may be useful for researchers and all stakeholder groups interested in the energy performance of Chinese provinces and other administrative regions, as well as those interested in the comparative analysis by using the decomposition method.

The EUFORIE project has also produced a comparative analysis between China and the European Union. These analyses are available in other EUFORIE deliverables mentioned in the list of references (Vehmas 2019; Giampietro et al 2019). National level analysis of China is available in Chen et al (2019a), and analyses for sectoral level (Chen et al 2019b), and analysis of the building/residential sector is also available (Panula-Ontto et al 2019).

D8.5. Comparative energy efficiency analysis between the EU and China

Vehmas, Jarmo

Executive Summary

Task

The purpose of this deliverable is to compare energy performance, energy efficiency, and energy efficiency policies in the European Union and in China, which are major energy consumer and emitters of greenhouse gas emissions at the global level. The comparison is done by using the literature, and by empirical analyses of energy performance carried out for the EU and in China in the EUFORIE project.

Methods

The major methods used in the analyses include chained incremental two-factor decomposition analysis and the LINDA modelling approach. Decomposition analysis and LINDA modelling have been used in the EUFORIE project for both the EU and China.

The decomposition approach relies on the following identities based on the Kaya identity

$$TPES = \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP$$

$$CO2 = \frac{CO2}{TPES} \times \frac{TPES}{FEC} \times \frac{FEC}{GDP} \times \frac{GDP}{POP} \times POP$$

where CO2 is carbon dioxide emissions from fuel combustion, TPES is total primary energy supply, FEC is final energy consumption, GDP is gross domestic product in real/constant prices, and POP is the amount of population. The LINDA modelling is based on the latter identity where the main drivers of CO_2 emissions are identified. CO2/TPES is change in carbon intensity of the primary energy mix, TPES/FEC ratio is a proxy for change in efficiency of the entire energy transformation system, FEC/GDP is change in energy intensity of the economy, GDP/POP is change in economic activity per capita, and POP is change in the amount of population.

Data

For this comparative analysis, the historical data used in the decomposition analysis has been updated up to the year 2015. The source for all data used in the decomposition analysis is International Energy Agency (IEA). Data for the LINDA models is taken from various sources. In the EuroLINDA model, major data sources include IEA for the CO_2 and energy data, World Bank for the economic data, and United Nations for the population data. In the ChinaLINDA model, the data has been mostly taken from the Chinese National Bureau of Statistics (NBS) databases.

Results

There is a major difference between the EU and China, both in CO_2 emissions from fuel combustion and the primary energy use. In China, CO_2 emissions from fuel combustion as well as total primary energy supply (TPES) have strongly increased in 1990-2015, but in the EU, both trends have slightly decreased during the same period. Carbon intensity of total primary energy supply has increased in

China, but decreased in the EU. This is visible also in their effects to the change of CO2 emissions and TPES during the period 1990-2015.

The TPES/FEC ratio, which is a proxy of efficiency of the entire energy transformation system, has also increased in China and decreased in the EU. Change in the TPES/FEC ratio has thus has an increasing effect to both total primary energy supply and CO_2 emissions in China, and a slightly decreasing effect in the EU.

Energy intensity, in terms of final energy consumption divided by gross domestic product (FEC/GDP), has decreased in both China and the EU. Change in energy intensity has had a larger decreasing effect to total primary energy supply and CO_2 emissions in China than in the EU.

Regarding the other drivers, change in economic activity (GDP/POP) and change in the amount of population (POP), the effect has been an increasing one in the EU and China. The effect of GDP/POP has been a decreasing one during the financial crisis in the EU especially in the years 2008-2009, while in China the increasing effect was a large one. Carbon intensity of the primary energy mix has slightly deceased during the studied period, but its annual effects to total primary energy supply and CO_2 emissions has varied a lot both in the EU and in China.

In the EU baseline scenario, significant decrease in primary energy and final energy use as well as CO_2 emissions takes place. The target of the share of renewable energies in the energy mix seems to be the most challenging one. Major result from the Chinese scenarios is that there is a major gap in 2020 between sectoral energy intensities between the baseline scenario and the energy efficiency scenario. Economic growth is of great importance from this perspective. Perhaps in the next five year plan China will follow the example of EU and set absolute targets for primary and final energy use, and preferable also for CO_2 emissions.

In this deliverable, a hypothesis was set on the better effectiveness of the EU 0nergy efficiency policy in comparison to China. The trends described above give a reason to think that among other things, the development might be a result of a contribution by energy efficiency policies. When looking at the major policy documents, there is a clear difference between China and the EU. Chinese five-year plans focus on relative targets and concrete actions such as investments in power plant capacity in the production side and development projects in the consumption side. EU directives focus on absolute targets, but the policy measures and actions are left at the disposal of Member States and the economic actors. This is a difference in the political system, which makes actual comparison of energy efficiency policies very difficult.

Use of the results

The results from the comparative analysis are useful for policy makers in the EU, and especially from the perspective of the negotiations related to the United Nations >Framework Convention on Climate Change (UNFCCC). The results are useful for all stakeholders (including policy makers, researchers, NGOs and energy industry/companies who are interested in energy and environmental performance of the EU and China, and for those who are interested in the methodology of performance analysis such as decomposition analysis and accounting type of modelling and scenario construction.

WP9 deliverables: Dissemination

D9.6. Report from public hearings in the EUFORIE project

Vehmas, Jarmo

Executive summary

Task, method and data

The purpose of this deliverable is to give an insight to the key findings from the EUFORIE public hearings, which include three national workshops organised in Italy, Spain and Germany, one set of national interviews made in Finland, and one roundtable discussion held in Belgium:

Title of the public hearing	International workshop on costs and benefits of energy efficiency – Scenarios for Italy and Europe	Workshop: Lessons learned from a critical analysis of European energy directives: Policy implications for Pla de l'Energia i Canvi Climàtic de Catalunya 2012-2020	Workshop: Beyond energy efficiency	Thematic interviews on energy efficiency and technology	Roundtable: "From physics to policy: Overcoming misperceptions in energy policy"
Location	Rome, Italy	Barcelona, Catalonia/Spain	Frankfurt a.M., Germany	Finland	Brussels, Belgium
Date	18 November, 201	13 April, 2017	2 June, 2017	May-June 2017	27 September 2018
Number of participants	32	43	26	11	10
Survey on energy efficiency	Yes	Yes	No	No	No
Respon-sible EUFORIE partner	Parthenope University of Naples, Italy	Autonomous University of Barcelona, Spain	Sustainable Europe Research Institute, Germany	University of Turku, Finland	University of Turku, Finland
Notes	In collaboration with the Federation of energy service companies (FEDERESCO)	In collaboration with Associació i Col·legi d'Enginyers Industrials de Catalunya (CEIC)	In collaborat-ion with Friends of the Earth Germany		Back-to-back event with the EMP-E conference "Modelling Clean Energy Pathways"

Results

The key findings from the workshops and interviews include the following:

- Energy efficiency should be dealt with at the level of relevant stakeholders and at the level where it can be monitored
- Energy efficient targets set at macro level do not necessarily lead to real improvements in energy efficiency.
- EU targets and policies dealing with energy efficiency are not clear for all stakeholders.
- Material/resource efficiency should be taken into account in addition to energy efficiency.
- There is a large potential for energy efficiency in many sectors of the society.
- Best technologies for improving energy efficiency include smart, automated heating/cooling, ventilation and lighting management systems for buildings, heat pumps, waste heat recovery technologies, and insulation.
- Institutional, organizational, economic and political issues, in addition to behavioral aspects of different energy consumers, are more important challenges of energy efficiency than technology.
- Lack or unawareness of financial incentives and short payback time with low energy price hinder implementation of energy efficient investments in practice.
- There is no superior policy instrument for promoting energy efficiency, and the opinions of instruments vary widely between EU Member States and stakeholder groups.

Results from the three workshops and the interviews only are included in this deliverable. The roundtable results are presented in a separate WP7 deliverable.

Use of the results

The results presented in this deliverable are useful for policy makers in the European Union and in the EU Member States. They are also of interest to all other stakeholders such as researchers, NGOs, and energy industry/companies, who are interested in energy performance of systems at various spatial, temporal and functional scales, energy and environmental policies, and the role of energy efficiency in policy target setting and implementation of policies and measures to improve energy efficiency.

D9.7. International EUFORIE Conferences on Energy Efficiency

Vehmas, Jarmo

Executive summary

Task

The purpose of this deliverable is to present the two conferences organised by the EUFORIE project in collaboration with other actors.

Results

The EUFORIE beneficiaries have made their contributions in these two international conferences:

- BIWAES (Biennial International Workshop Advances in Energy Studies) 2017 conference "Energy Futures, Environment and Well-being", organized on 25-28 September 2017 in Naples, Italy, by Parthenope University of Naples.
  Website:
  http://biwaes.uniparthenope.it/
  Agenda:
  http://biwaes.uniparthenope.it/wp-content/uploads/2017/09/BIWAES2017_PROGRAMME_23-September-2017.pdf
- Futures conference 2018 "Energizing Futures – Sustainable Development and Energy in Transition", organized on 13-14 June 2018 in Tampere, Finland, by University of Turku, Finland Futures Research Centre.
  Website:
  https://futuresconference2018.wordpress.com/
  Agenda:
  https://futuresconference2018.files.wordpress.com/2018/05/energizing_program2.pdf

In these two conferences, altogether 19 presentations based on the results from the EUFORIE project were given.

Proceedings of the BIWAES conference has been published and it is available at http://castor.tugraz.at/doku/BIWAES2017/BIWAES_2017.pdf.

Proceedings of the Energizing Futures conference is forthcoming and will be published in the FFRC eBooks by University of Turku, Finland Futures Research Centre.

The EUFORIE project has also been presented in the European Modelling Platform for Energy (EMP-E) conference "Modelling Clean Energy Pathways" on 25-26 September 2018 in Brussels, Belgium.

Use of the results

The EUFORIE contributions given in these conferences are useful for all stakeholders (policy makers, researchers, NGOs/citizens and energy industry/companies) who are interested in research focusing on energy efficiency at different spatial, temporal and functional scales, and the energy, material and environmental performance of EU Member States, companies and different functional systems.