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Synthesis of published papers in a scientific ENEFIRST booklet

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FOREWORD

The ENEFIRST project contributed to provide policy makers, stakeholders, researchers and analysts with resources to make the Energy Efficiency First (EE1st) principle operational. It was focused on buildings and their energy supply (especially the power sector and district heating). The project combined policy analysis and quantitative assessments about the implementation of EE1st, with a process of continuous exchanges with stakeholders.

This booklet gathers the abstracts of the peer-reviewed papers summarizing the main findings from the projects, and submitted to scientific journals (Part 1 of the report) or presented at international conferences (Part 2 of the report).

The full reports presenting all the details of the research done in ENEFIRST can be found at: https://enefirst.eu/reports-findings/

Before their publication on the website, the main findings of ENEFIRST were discussed with stakeholders and experts at online workshops. After their publication, the main findings were disseminated with webinars. The proceedings of the workshops and webinars can be found at: https://enefirst.eu/events/

Moreover, references relevant to the EE1st topic and identified along the project were gathered in a group library on Zotero, the ENEFIRST Library of references (available in open access).

Note: at the time of finalizing this report, most of the papers submitted to journals were still in their review process. The web-links mentioned for these papers are the links to the journals where they have been submitted, and where they will be available once published, if approved by the reviewers and editors of these journals.

1 PAPERS SUBMITTED TO SCIENTIFIC JOURNALS

1.1 Conceptualising the Energy Efficiency First principle: insights from theory and practice

Authors:

Tim Mandel[1], Zsuzsanna Pató[2], Jean-Sébastien Broc[3], Wolfgang Eichhammer[1,4]

[1]*Fraunhofer Institute for Systems and Innovation Research ISI (Fraunhofer ISI), Karlsruhe, Germany*

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Abstract:

The Energy Efficiency First (EE1st) principle has recently been placed onto the political agenda in the European Union (EU). While the general rationale for EE1st is described in EU legislation and supporting literature, a common understanding of the principle's implications for energy-related planning, investment and policymaking is still missing. Based on an exploratory review of the literature, the objective of this article is to improve the theoretical understanding of EE1st. First, it develops a conceptual framework, describing EE1st as a decision-making principle that prioritises demand-side resources over supply-side alternatives whenever these provide greater value to society in meeting decision objectives. Second, it highlights the unique aspects of EE1st by systematically comparing the principle with associated concepts, such as Integrated Resource Planning. Third, it provides theoretical justification for EE1st by describing the economic rationale behind the principle. Fourth, it outlines policy considerations for its practical implementation. In sum, the EE1st principle is shown to have a compelling theoretical background that can help inform the design of effective policy interventions in order to move from principle to practice.

Keywords:

energy efficiency first, energy markets, energy supply, market failure, energy policy

This paper is published and available in open access in the special issue on Energy Efficiency First in the Energy Efficiency *journal:* https://doi.org/10.1007/s12053-022-10053-w

1.2 Energy Efficiency First in the power sector: incentivising consumers and network companies

Authors:

Zsuzsanna Pató[1], Tim Mandel[2]

[1]*Regulatory Assistance Project (RAP), Brussels, Belgium*

[2]*Fraunhofer Institute for Systems and Innovation Research ISI (Fraunhofer ISI), Karlsruhe, Germany*

Abstract:

Energy Efficiency First (EE1st) is an important concept that, if implemented, will minimise the cost of the energy transition by exploiting the end-use energy efficiency and demand response potential of end users. The power sector is particularly relevant for the application of the EE1st principle as it needs to be decarbonised early, demand is to grow due to the electrification and due to the increasing value on demand flexibility to maintain system balance. In this paper we show that consumers need to be considered as multiple resources for the power system and examine key regulatory tools to mobilize consumers to offer their flexibility and DSOs to use this flexibility to reduce the need for network asset investment. The pricing of energy and network is key in delivering demand-side flexibility. At the same time DSOs need to consider them in their network planning by law, and regulators are encouraged to incentivise them to integrate the consumers in network operation innovatively. The European regulation provides an appropriate framework for the implementation of the principle in the power sector. It is now the tasks of national regulators to implement them effectively.

Keywords:

Energy Efficiency First, power, demand-side resources, flexibility, DSOs

This paper has been submitted to the special issue on Energy Efficiency First in the Energy Efficiency journal.

1.3 Decarbonization of district heating and deep retrofits of buildings as competing or synergetic strategies for the implementation of the efficiency first principle

Authors:

Eftim Popovski[1], Mario Ragwitz[2], Heike Brugger[3]

[1] *Institute for Resource Efficiency and Energy Strategies - IREES, Karlsruhe, Germany*

[2] *Fraunhofer Institute for Energy Infrastructure and Geothermal Systems IEG, Karlsruhe, Germany*

[3] *Fraunhofer Institute for Systems and Innovation Research ISI (Fraunhofer ISI), Karlsruhe, Germany*

Abstract:

This paper discusses the compatibility of district heating (DH) networks with deep retrofits of buildings under various European climate conditions and city typologies. The study analyses five cities with different DH market shares, climate zones, population densities, and transferability potentials. First, we have forecasted population, heated floor area, and share of floor area per construction period until 2050, and then calculated three different heat demand scenarios for varying building refurbishment rates of 1%, 2%, and 3% of the total floor area. Second, future suitable DH regions with min 25 GWh/km² networks were identified. By applying a bottom-up GIS model, based on the type of city area, number of buildings, street length, and heat density, the DH distribution capital and operation costs were calculated. Lastly, to compare the total cost of heat supply for each scenario, the cost of individual heat per building type was calculated.

The results show that even in the scenarios with high refurbishment rates of 3%, high percentage of the built-up areas, between 23% and 68% depending on the city typology, are suitable for DH supply in 2050. The share of DH from the total heat supply varies between 49% and 83%. An increase of the DH price between 14%-35%, depending on the scenario and case study can be expected due to the reduced heat densities compared to the current ones. Nevertheless, maximizing the DH connection rates in the identified regions leads to lower total cost of heat in almost all the analysed case studies.

Keywords:

Energy Efficiency First principle, District heating networks, Bottom-up energy modelling, Geographic information system, Deep energy retrofit, Municipal heat planning

This paper has been submitted to the special issue on Energy Efficiency First in the Smart Energy journal.

1.4 How cost efficient is energy efficiency in buildings? A comparison of building shell efficiency & heating system change in the European building stock

Authors:

Marcus Hummel[1,2], Andreas Müller[1,2], Sebastian Forthuber[1], Lukas Kranzl[1], Bernhard Mayr[2], Reinhard Haas[1]

[1] *Technische Universität Wien, Energy Economics Group, Vienna, Austria*

[2] *e-think energy research, Vienna, Austria*

Abstract:

Mitigating CO_2 emissions for space heating (SH) and hot water (HW) preparation in buildings is key for reaching climate protection targets. In this context it is important to understand meaningful balances between CO_2 reduction through renovation activities and through the change of heating systems. In this work we develop such cost optimal balances for different system settings with the Invert/Opt model. The model hereby optimizes the measures applied in each building, so that the system costs for SH and HW preparation are minimized under given constraints for a given country. For each building, about 500-1000 options are considered. We calculate scenarios for all countries of EU-27 reflecting a 95% reduction in CO_2 emissions for SH and HW with a mix of direct and indirect RES technologies. The scenarios differ in the constraints related to the choice of building shell related measures.

The results show that a high share of thermal renovation on total upcoming refurbishment activities until 2050 is cost efficient to reach a 95% CO_2 reduction in the EU-27 building stocks. Allowing 90% of the buildings in the stock of each EU-27 country to implement a thermal renovation in case a refurbishment activity is needed leads to around 4% lower system costs until 2050 (13 billion EUR/yr) compared to restricting the share to 35%. On average, older buildings reduce energy needs stronger than newer buildings. However, also in newer buildings a combination of thermal renovation and heating system change is often the least cost option to reduce system wide CO_2 emissions.

Keywords:

95% CO_2 reduction, European building stock, building retrofit, heating system change, building stock model, Invert/Opt, cost-optimal heat savings

This paper has been submitted to the special issue on Energy Efficiency First in the Energy Efficiency journal.

1.5 Energy Efficiency First in the European building sector: Investigating least-cost pathways for net-zero emissions

Authors:

Tim Mandel[1], Lukas Kranzl[2], Eftim Popovski[3], Frank Sensfuß[1], Wolfgang Eichhammer[1,4]

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[4]*Utrecht University, Copernicus Institute of Sustainable Development, Utrecht, the Netherlands*

Abstract:

The « Energy Efficiency First » (EE1st) principle aims to prioritize investments in energy efficiency, demand response and other demand side resources whenever these are more cost-effective from a societal viewpoint in meeting policy objectives than generators, networks and other supply-side resources. Putting EE1st in practice requires detailed modelling to determine actual resource portfolios that provide the greatest value to society – not only in terms of monetary costs, but also concerning multiple impacts (e.g. health effects). This work provides an in-depth quantitative assessment of the EE1st principle for the European building sector. It employs a set of four soft-coupled bottom-up energy models (FORECAST, INVERT, ENERTILE, NETHEAT) and three normative scenarios to investigate what level of demand and supply-side resources would be most cost-effective to transition to net-zero emissions for the EU building sector by 2050. To determine monetary system costs, the models cover residential and non-residential buildings, as well as generation, network, and storage infrastructures in the electricity, heat, and gas sectors. Additional modelling is used to provide a monetized approximation of various multiple impacts. Preliminary results reaffirm that the EU should boost building renovation and other demand-side measures to ensure a socially optimal transition to a net-zero economy.

Keywords:

energy efficiency first, energy markets, energy supply, market failure, energy policy

This paper has been submitted to the special issue on Energy Efficiency First in the Energy Efficiency journal.

1.6 Cost-optimality considerations for staged building renovation under different energy price settings

Authors:

Iná Maia[1], Daniel Harringer[1], Lukas Kranzl[1]

[1] *Technische Universität Wien, Energy Economics Group, Vienna, Austria*

Abstract:

Empirical studies about real-life renovation activities have strongly evidenced that most of them are performed partially – meaning that measures to increase energy efficiency are not performed in a single stage for all building elements and components but rather stepwise. As a reaction to that evidence, the EPBD 2018/844/EU introduced a new instrument: the building renovation passport including an individual building step-by-step renovation roadmap. However, the cost-optimality considerations of energy performance standards are focusing on single stage renovation. The main objective of the present paper is to understand how decarbonisation targets and energy efficiency targets can be achieved using different combinations and timing of retrofitting steps in staged renovation. When defining the combination of measures, both the single-stage and the step-by-step retrofitting approach are considered. The measures include different categories: improvement on the building envelope, heat supply and renewable energy generation. For assessing the cost-effective renovation, and delivering the cost optimal solutions, the methodology applied is the one used in IEA EBC Annex 56: calculation procedures to assess cost-optimal and cost-effectiveness of energy renovation activities. The retrofit global costs and the resulting building's energy performance for several variants of measures' combination are calculated. The building energy performance calculation is a yearly-base steady-state calculation determined by the German norm DIN 18999 (that partly relies on the ISO 52000 series). Moreover, the investment costs are based on country-specific databases and represent the material and labour costs. A particular emphasis will be given to the impact of different energy price levels and paths. The results show cumulated costs and energy demand of various single-stage and step-by-step cost-optimal combinations for reference buildings under different conditions. The impact of price paths on cost-optimal combination of renovation measures is significant, with key conclusions on the relevance and required adaptation of the cost-optimality methodology. Moreover, the timing of measures strongly depends on household budget constraints and lifetime of building components. Specific policy instruments are required to overcome them. In this context, we discuss how our insights can support the policies design schemes that aim to accelerate the EU's building stock decarbonisation process.

Keywords:

Staged building renovation, cost-optimality calculation, renovation passport, EPBD, energy efficiency

This paper has been submitted to the special issue on Energy Efficiency First in the Smart Energy journal.

2 PAPERS PRESENTED AT INTERNATIONAL CONFERENCES

2.1 Conceptualizing the "Energy Efficiency First" principle: from foundations to implementation

Authors:

Tim Mandel[1], Zsuzsanna Pató[2], Jean-Sébastien Broc[3]

[1]*Fraunhofer Institute for Systems and Innovation Research ISI (Fraunhofer ISI), Karlsruhe, Germany*

[2]*Regulatory Assistance Project (RAP), Brussels, Belgium*

[3]*Institute for European Energy and Climate Policy (IEECP), Amsterdam, the Netherlands*

Abstract:

Energy Efficiency First (E1st) has recently entered the EU policy agenda. Although its general rationale has been described in the Governance Regulation and in grey literature, a lack of shared understanding remains about the principle's implications for investment and policymaking.

This paper seeks to synthesise views on the principle, enhance its conceptual foundations and illustrate possible routes to implementation.

First, it explores the historical and practical background of E1st by comparing the principle with similar regulatory concepts from outside the EU, including Least-Cost Planning, Integrated Resource Planning, and Demand-Side Management. This shows that the basic idea behind E1st, i.e. establishing a level playing field for demand- and supply-side resources, is not entirely new and that lessons can be learnt from related concepts.

Second, it provides a theoretical foundation for E1st. By looking at the topic of the energy efficiency gap, as well as market and behavioural failures, the paper explains why, at present, demand- and supply-side resources are not on equal footing. It then explains what would need to change to establish an adequate balance.

Third, based on this conceptual background, the article discusses possible avenues for putting E1st into practice within the EU's institutional framework. It does so by introducing two complementary institutional arrangements for E1st: (i) centralised decision-making (e.g. prescription of cost-benefit analysis in network planning) and (ii) decentralised market-based decision-making (e.g. ensuring market access for demand-side resources in power markets).

This paper has been presented at the conference ECEEE 2021 Summer Study on 7 June 2021. The paper and presentation can be found at:
https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2021/2-policy-innovations-to-ensure-scale-and-sustain-action/conceptualizing-the-energy-efficiency-first-principle-from-foundations-to-implementation/

2.2 "Efficiency First" in practice

Authors:

Zsuzsanna Pató[1], Tim Mandel[2], Jean-Sébastien Broc[3]

[1]*Regulatory Assistance Project (RAP), Brussels, Belgium*

[2]*Fraunhofer Institute for Systems and Innovation Research ISI (Fraunhofer ISI), Karlsruhe, Germany*

[3]*Institute for European Energy and Climate Policy (IEECP), Amsterdam, the Netherlands*

Abstract:

Even though E1st (which is more and less than energy efficiency) is already established in EU legislation, the ways to put it into practice is a yet an undiscovered territory for policy makers in the Member States. This is reflected in the fact that mandatory reporting on E1st does not go further than using the term in the NECPs submitted by Member States in 2020. However, implementation of the principle in all energy system decision making is crucial to keep the cost of the energy transition down and to avoid lock-in in infrastructure assets that will become stranded before the end of their lifetime.

Investment decisions are taken by consumers (behind the meter) and network and generation companies (in front of the meter). The investment decisions of final consumers and energy companies are strongly interrelated: households' demand-side, storage and on-site renewable generation investments reduce the needed volume (and change the timing) for networked supply. Hence, the policies and regulation aiming at final consumers, energy use and production have important implications at higher levels, such as the city, region, country or continent.

Several 'real word' examples have actually implemented the idea of E1st, even though they are not named as such. This presentation will 1) provide a two-dimensional framework to organise the diversity of situations and approaches of applying E1st, and 2) discuss a few real word cases from Europe and the US from those that are publicly available on the ENEFIRST website. These examples can serve as a starting point to discuss a more comprehensive and consistent application of the principle. For more examples see: https://enefirst.eu/wp-content/uploads/D2-2-Report-on-international-experiences-with-E1st.pdf

This abstract has been presented at the conference ECEEE 2021 Summer Study on 7 June 2021. The presentation can be found at:
https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2021/2-policy-innovations-to-ensure-scale-and-sustain-action/efficiency-first-in-practice/

2.3 What does the energy efficiency first principle mean in practice?

Authors:

Jean-Sébastien Broc[1], Zsuzsanna Pató[2], Senta Schmatzberger[3], Janne Rieke Boll[3], and Tim Mandel[4]

[1]*Institute for European Energy and Climate Policy (IEECP), Amsterdam, the Netherlands*

[2]*Regulatory Assistance Project (RAP), Brussels, Belgium*

[3]*Buildings Performance Institute Europe (BPIE), Berlin, Germany*

[4]*Fraunhofer Institute for Systems and Innovation Research ISI (Fraunhofer ISI), Karlsruhe, Germany*

Abstract:

Energy Efficiency First (E1st) is now an established principle of EU energy policy. Energy efficiency is one of the five dimensions of the Energy Union. To emphasise the prominent role of energy efficiency, the E1st principle has been embedded in various legislative pieces of the Clean Energy for All package adopted in 2018-2019 (European Commission 2016), especially with an official definition included in the overarching Governance Regulation of the Energy Union ((EU) 2018/1999).

In line with the approach of the Governance Regulation, the E1st principle is about a more integrated view of the energy systems, considering options on the supply side and demand side with a level playing field. While it might look straightforward at first sight, it requires a paradigm shift to consider more systematically the multiple impacts of investment decisions related to energy systems, as well as multiple timeframes (from short to long term). To address this, there is a clear need of resources to help policy makers and stakeholders walk the talk.

The ENEFIRST project aims at developing such resources and at showing how the E1st principle can be implemented in practice. We started by analysing the background of the E1st principle and developing a definition that can be used to operationalize the concept. The next step was to review 16 “real-life” examples where the E1st principle, or similar approaches, have been implemented.

The non-comprehensive collection of examples shows that the benefits from implementing E1st can occur at various scales and time horizons. From short-term flexibility in the energy demand (e.g. with Time-of-Use tariffs or demand response) to long term reductions in GHG emissions by avoiding lock-in effects for energy savings in buildings. From limiting the needs of on-site heat generation (as done with the Fabric first approach developed in Ireland) to avoiding building a new power plant (as done in California).

This review of examples and a first general analysis of barriers show that implementing E1st goes beyond adapting the frameworks for investment decisions to accommodating demand-side resources. It requires to have a broader view of the possible solutions to meet the energy needs, to break the silos, favour more interactions and coordination among actors of the supply-side and demand-side, and take the entire energy system and its implications on society into account.

This paper has been presented at the conference World Energy Sustainable Days 2021 on 25 June 2021. The paper and presentation can be found at: https://enefirst.eu/wp-content/uploads/WSED2021_ENEFIRST_paper.pdf).

2.4 Efficiency First, from words to actions: practical examples from the ENEFIRST project

Authors:

Janne Rieke Boll[1]

[1]*Buildings Performance Institute Europe (BPIE), Berlin, Germany*

Abstract:

Efficiency First (E1st) is now an established principle of the EU energy policy. It has been embedded in various legislative pieces of the Clean Energy for All package. However the review of the NECPs has shown that this concept might still remain vague for policy makers and implementers.

This presentation will illustrate through practical examples what E1st can mean for policy making or decision processes with a focus on the buildings sector, and what added value it brings compared to "classical" energy efficiency policies. It will dive into the main barriers and stakeholder actions required to implement E1st across policy areas.

This presentation is based on the first results of the Horizon 2020 project ENEFIRST that aim at operationalizing the E1st principle for the buildings sector.

This abstract has been presented at the C4E Forum on 22 September 2021. The presentation can be found at: https://enefirst.eu/events/presentation-of-enefirst-at-the-c4e-forum/

2.5 Efficiency First in the European building sector: Investigating least cost pathways for net zero emissions

Authors:

Tim Mandel[1]

[1]*Fraunhofer Institute for Systems and Innovation Research ISI (Fraunhofer ISI), Karlsruhe, Germany*

Abstract:

The building sector accounts for 36% of the global final energy demand and 39% of energy-related CO_2 emissions, making them pivotal to achieve climate neutrality. The “De-Carbonising the Building Sector” session on 27 October 2022 (14:00-15:30 CET) aimsed to provide quantitative evidence on different pathways to decarbonise the building sector by 2050. With the help of different scenarios, this session will highlight the role of energy-efficiency, net-zero energy building constructions and renovations, and co-benefits to achieve climate neutrality by 2050.

Tim Mandel presented on “Efficiency First in the European building sector: Investigating least-cost pathways for net-zero emissions”

This abstract has been presented at the EMP-E (Energy Modelling Platform – Europe) 2021 conference on 27 October 2021. The presentation can be found at: https://enefirst.eu/events/enefirst-presentation-at-emp-e-2021-re-energising-sustainable-transitions-in-europe/

2.6 Policy design for Energy Efficiency First: taking stock of measures for moving from principle to practice

Authors:

Tim Mandel[1], Zsuzsanna Pató[2], Benigna Boza-Kiss[3]

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[3]*Central European University, Vienna, Austria*

Abstract:

Energy Efficiency First (EE1st) means balancing end-use energy efficiency and other demand-side resources with energy generation, networks and other supply-side resources from a societal cost viewpoint. In parallel with its evolving legal status in EU legislation, a growing literature discusses policy approaches to help implement the principle. However, a theoretically substantiated framework for these policies is not yet established. This paper aims to review and categorize dedicated policy approaches for the implementation of the EE1st principle in the EU. First, we provide a theoretical background to policy design for EE1st by referring to market failure theory and explaining how policies addressing EE1st differ from traditional energy efficiency policies. Second, we link theory and practice by taking stock of potential policy approaches for EE1st, attaching them to individual market failures, and thus providing a comprehensive catalogue of policies for moving from principle to practice. The paper shows that there is no single policy lever for implementing the principle. Instead, EE1st requires a broad policy response that goes beyond the established energy efficiency policy portfolio. We conclude by identifying promising innovative policies warranting more detailed assessment, including electricity market reforms moving towards marginal cost pricing, performance-based regulation for network companies and more.

This paper has been presented at the ECEEE 2022 Summer Study on 6-10 June 2022. The paper and presentation can be found at:
https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2022/3-policy-finance-and-governance/policy-design-for-energy-efficiency-first-taking-stock-of-measures-for-moving-from-principle-to-practice/

2.7 Energy efficiency first policy landscapes for buildings: case studies in Germany, Hungary and Spain

Authors:

Benigna Boza-Kiss[1], Senta Schmatzberger[2], Jean-Sébastien Broc[3], Xerome Fernández Álvarez[2], Diana Ürge-Vorsatz[1]

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Abstract:

Recognizing the value of energy efficiency improvements as the biggest domestic energy resource in the EU, Energy Efficiency First (EE1st) is a cross-cutting principle of EU energy policy. It is set out in the recast Energy Efficiency Directive, supported by a set of practical recommendations. Implementing EE1st challenges the way we compare demand-side and supply-side options, assessing the basis for and practicalities of prioritising demand-side options.

The Renovation Wave as part of the Green Deal emphasizes the importance of acting on energy efficiency of buildings. Implementing the EE1st principle here benefits the entire energy system, as buildings are able to reduce the energy demand and thereby have a direct impact on infrastructure needs.

This paper reviews EE1st implementation for the building sector in German, Hungary and Spain showing a diversity of preconditions. The overall buildings policy frameworks are analysed to determine if the two examples of EE1st policies discussed in this paper could be best suited for transferability in the realm of the institutional, financial and policy system. Germany has an already strong building code, which could still be strengthened to overcome barriers identified, such as silo thinking. Spain has strong renovation funding programmes which could be defined in terms of composite indicator instead of primary energy to lead to an EE1st approach. Hungary should increase the overall building code stringency and should integrate energy requirements into funding schemes. EE1st aspects coupled with rapid improvements in the decision-making process, in collaboration among decision-making and implementation bodies, as well as efficiency criteria in many, but at least in grant decisions could result in economic, social and climate benefits. The findings have been validated through expert consultations in the three countries through the ENEFIRST project.

This paper has been presented at the ECEEE 2022 Summer Study on 6-10 June 2022. The paper and presentation can be found at:
https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2022/7-policies-and-programmes-for-better-buildings/energy-efficiency-first-policy-landscapes-for-buildings-case-studies-in-germany-hungary-and-spain/

2.8 Energy Efficiency First and Multiple Impacts: integrating two concepts for decision-making in the EU energy system

Authors:

Tim Mandel[1], Ivana Rogulj[2], Benigna Boza-Kiss[3], Lukas Kranzl[4], Ece Özer[4], Andreas Müller[5]

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Abstract:

The principle of Energy Efficiency First (EE1st) has recently gained traction in the political debate. It aims to consider and prioritise investments in demand-side resources (e.g. end-use energy efficiency) whenever these cost less or deliver more value than default energy infrastructure (e.g. networks). Meanwhile, energy efficiency is increasingly associated with a variety of environmental, economic, and social benefits known as multiple impacts (MI). It is frequently argued that taking thorough account of the EE1st principle in energy-related investment and policymaking means to incorporate MI in the decision-making process to ensure a fair comparison of resource options. However, a theoretical account of how the two concepts fit together is still missing. Moreover, there is an ongoing lack of quantitative evidence on individual MI. The objective of this paper is twofold. First, based on an expert workshop and a literature review, it aims to integrate the state of knowledge on the concepts of EE1st and MI. This concerns the theoretical interlinkages between the two concepts as well as the possible role of different decision-support frameworks (e.g. cost-benefit analysis). Second, the paper provides evidence on the magnitude of selected MI from a model-based assessment for the EE1st principle in the EU-27. Three scenarios are compared for the MI of air pollution and indoor comfort. We find that factoring in MI certainly affects the trade-off between demand-side and supply-side resources, making it critical to include them in model-based assessments in the scope of EE1st.

This paper will be presented at the Energy Evaluation Europe 2022 conference on 28-30 September 2022. The paper and presentation will then be available at: https://energy-evaluation.org/resources/