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ORIGINAL ARTICLE

How first comes energy efficiency? Assessing the energy efficiency first principle in the EU using a comprehensive indicator-based approach

Mara Chlechowitz · Matthias Reuter · Wolfgang Eichhammer

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Abstract The energy efficiency first (EE1) principle was defined and established as a leading principle of the European Union's energy policy with the Clean Energy for All Europeans package in 2016. The principle requires demand resources to be considered on par with supply-side solutions and prioritized whenever they are less costly or deliver more value than alternative options. This approach should be applied in every planning process, decision-making, and investment regarding the energy sector. In order to examine to which degree the EE1 principle is actually implemented by the Member States, we developed a composite indicator, which consists of 13 criteria. These criteria capture the multiple facets of the EE1 principle and thus can also be used as a guide for the EU Member States in their operationalization of the EE1 principle. After the development of the methodology, the indicator-based approach is tested to assess the implementation of the EE1 principle in the national energy and climate plans of 14 Member States. The aim of this step is to demonstrate the feasibility of the indicator and its applicability as an assessment tool across different countries in the EU. The results imply that the fundamentals of the principle are understood and realized. Nevertheless, most countries would still fail to ensure an equal treatment between supply and demand-side resources and neglect the multiple benefits associated with energy efficiency improvements. However, those finding should be considered with caution since only limited data was used to test the operationalization of the indicator on the EE1 principle.

Keywords Energy efficiency first · Composite indicator · Energy policy · European Union · Energy poverty · Sufficiency

This article is part of the Topical Collection on *Making the Energy Efficiency First Principle Operational*

M. Chlechowitz · M. Reuter · W. Eichhammer (✉)
Fraunhofer Institute for Systems and Innovation Research (ISI), Breslauer Straße 48, 76139 Karlsruhe, Germany
e-mail: wolfgang.eichhammer@isi.fraunhofer.de

W. Eichhammer
Copernicus Institute of Sustainable Development, Utrecht University, Princetonlaan 8a, 3584 CB Utrecht, The Netherlands

Introduction

The relevance of energy efficiency (EE) in building a secure, sustainable, and affordable energy system has been recognized both on the international and on the European level. In 2013, the International Energy Agency coined EE as "the first fuel" (IEA, 2013), which was then adapted by the European Union (EU) in the EU 2030 climate and energy policy framework (EC, 2015). EE constitutes one of the five pillars of the Energy Union, which further include energy security, solidarity, and trust; the internal energy market; decarbonization of the economy; and research,

innovation, and competitiveness. In this context, EE takes on an overarching role, as it presents a cost-effective option to reach a variety of goals due to the fact that "*the cheapest and cleanest source of energy is the energy that does not need to be produced or used*" (EC, 2016).

Despite this, the progress in EE has slowed down over the last decade across the EU. While EE improvements in final energy consumption grew by 1.4% annually between 2000 and 2007, the progress decreased to an annual growth rate of 1.1% afterwards (ODYSSEE-MURE, 2020). Because the Member States (MS) across the EU continue to underinvest in energy efficient opportunities and demand-side measures, a significant share of economic EE potentials remains untapped (Economidou et al., 2011). As a consequence of this gap, the Energy Union agreed on the necessity for an overarching mandate to ensure the exploitation of the economic EE potentials. For this purpose, the energy efficiency first (EE1) principle was defined and established as a leading principle with the Clean Energy for All Europeans package proposed in 2016 and adopted in 2018–2019 (EU, 2018). The proposed update of the EED dedicates Article 3 to the application of the EE1 principle in the Member States (EC 2021).

In short, the principle requires demand-side options to be considered on par with supply-side solutions in energy policy and prioritized whenever they are less costly or deliver more value than alternative options. The ubiquity of EE1 further demands its application in every planning process, decision-making, and investment regarding the energy market. While the preferential treatment of less costly demand-side solutions seems like a logical and common-sense approach to policymaking, the insufficient EE investments and measures show that this is not the standard in EU policymaking. The uptake of cost-efficient and energy efficient technologies are impeded by a variety of market barriers like limited access to capital, information, or behavioral issues (Thollander & Palm, 2013). Furthermore, the traditional prioritization of supply-side solutions on the political sphere as well as in business decisions still prevails today and may cause policymakers and investors to overlook cost-efficient EE opportunities. Therefore, the EE1 principle represents a change to the paradigm of the energy system, by moving EE on the top of the agenda and demanding it to be treated as the first fuel.

Because EE1 goes beyond the implementation of EE measures and the introduction of specific targets, the extent to which the EE1 principle has been incorporated by the MS cannot be assessed by common EE indicators like final energy consumption and energy intensity. Instead, the indicator needs to contain information about the treatment of supply- and demand-side options in the policymaking process and decision-making as well as on the management of obstacles and challenges to the uptake of EE improvements. The objective of this paper is to develop criteria, on how to assess the EE1 principle in policymaking, and aggregate those to a single indicator. The set of criteria should reflect the different aspects of EE1, be comparable across countries, and straightforward, so that national policymakers can use them as a guideline or checklist for operationalizing the EE1 principle. The second objective of this paper is to test the applicability of the indicator, which will be developed in course of this paper, by assessing the degree to which the EE1 principle was implemented in the development of the National Energy and Climate Plans (NECPs).[1]

For this purpose, "Defining the EE1 principle" section of this paper provides a detailed definition of the EE1 principle and provides an insight into its operationalization. Based on this, a total of 13 criteria are developed, which are presented in the "Methodology" section. Depending on the relevance of the criteria, different weights are assigned to them, which are then aggregated to a single indicator. The feasibility assessment of the indicator follows in the "Results" section, in which the integration of the EE1 principle in national policymaking is assessed. The assessment is based on the NECPs and interviews with stakeholders of 14 MS. After the results are presented, conclusions are drawn in the "Discussion" section, as well as the limitations and future application of the indicator discussed.

[1] The NECPs were introduced under the regulation on the governance of the Energy Union ((EU) 2018/1999) and require each MS to outline a plan, on how they intend to reach the national and European energy and climate goals, starting from 2021 until 2030.

Defining the EE1 principle

Background and definition

At the EU level, the principle first gained attention with the launch of the Energy Union in 2015 and entered the political and policy sphere with the Clean Energy for All Europeans package (ENEFIRST, 2019). The principle has further been included in subsequent regulations and amendments of a variety of directives and was first published in a Governance Regulation (EU, 2018/1999) by late 2018 in the following Article 2(18):

"*energy efficiency first*" *means taking utmost account in energy planning, and in policy and investment decisions, of alternative cost-efficient energy efficiency measures to make energy demand and energy supply more efficient, in particular by means of cost-effective end-use energy savings, demand response initiatives and more efficient conversion, transmission and distribution of energy, whilst still achieving the objectives of those decision* (EU, 2018, Article 2, 18).

Further interpretations of the EE1 principle are given on the European level (EC, 2016, 2019), by the German government (BMWI, 2016) as well as by numerous NGOs and European think tanks (Bayer, 2015; Coalition for Energy Savings, 2015; Cowart, 2014; Cowart et al., 2015). While they slightly differ in terms of details and formulation, they all contain common elements. In the following, these core elements of the EE1 principle are summarized in three statements, which together provide an overview of meaning behind the principle.

Statement 1: energy demand is not fixed

The EE1 principle moves away from the traditional approach of considering energy demand solely as autonomous in the energy equation, which cannot be influenced. Instead, under the EE1 principle, energy demand presents an input variable, which can be and should be influenced. Hence, additionally to supply options — like grid expansion — demand-side management should be taken into account (Gellings, 2017).

Statement 2: equality of supply and demand resources

The principle neither equals a specific level of EE nor does it promote a general superiority of demand side solutions. Instead, EE1 requires demand resources to be considered on par with other options and prioritized when they are less costly or deliver more value than alternative options. To ensure the equal treatment of both solutions, it is necessary that the full scope of costs and benefits are included in the comparison. Thereby, the EE1 principle acknowledges that both costs and benefits go beyond economic aspects and additionally include social and environmental benefits. The results of the CBA, and thus also the assessment of the economic EE potentials, depend on the definitions applied in this context as well as the assessment methodology (ENEFIRST, 2019).

Statement 3: ubiquity in all energy policies and strategies at any level

As noted previously, according to the EE1 principle, EE is more than a tool to achieve a final target like energy savings. It rather transfers EE to a higher level by integrating it in energy policies and strategies. As a resource on its own or as a first fuel, EE contributes to all five pillars of the Energy Union. To guarantee that energy efficiency comes first across all decisions related to the energy system, policymakers on the national, regional, and local level are supposed to apply the principle in all energy planning, policy, and investment decisions in order to optimize the energy system. Furthermore, the respective governments are urged to involve private and business entities, so that the EE1 principle is also embedded in their investment decisions (EU, 2018).

Operationalization of the EE1 principle

To reach carbon neutrality by the middle of the twenty-first century is a key objective of the European Green Deal and in line with the EU's commitment to global climate action under the Paris Agreement. As part of this commitment, the European Commission advocates that the benefits of the decarbonization should be linked to improve the overall well-being and health of citizens and future generations. The transition of the energy sector plays as crucial role

in this endeavor since energy-related greenhouse gas emissions account for more than 75% of the EU's total emissions. The reduction of the energy demand through EE improvements presents a cost-effective and impactful way to curb the GHG emissions in the energy sector and contribute to the climate strategy of the EU.

Apart from environmental benefits such as lower GHG emissions and better air quality, EE improvements are associated with further benefits for the society. Those benefits are known as the multiple benefits (MBs) of EE and encompass social, environmental, and economic benefits (IEA, 2014; Reuter et al., 2020). This means that putting EE first and promoting investments into EE not only contributes to the decarbonization of the EU but also to goal of improved well-being and health of all citizens. While in particular the environmental benefits might be more obvious when EE investments replace a costly expansion of energy infrastructure or fossil fuel, putting EE first is also relevant in countries with a high share of renewable energy. An excessive use of renewable energy sources can potentially slow down the process of decarbonization and puts a burden on the environment in form of excessive land-use, habitat loss, or disruptions to natural river flows (Rosenow & Cowart, 2019).

To guarantee that EE comes first across the energy system and unlocks the multiple benefits associated with EE, various actors from different levels need to be involved in making the EE1 principle operational. Those actors include policymakers, regulation authorities, energy suppliers, network operators, and consumers (ENEFIRST, 2019). Depending on the actor, the potential contribution to realize the EE1 principle differs.[2] Therefore, it is important to emphasize that the focus in this paper, and the indicator-based approach to the EE1 principle developed in this course, relates to the implementation of the EE1 principle by policymakers. In this context, policymakers refer to institutions on the national and regional level, who influence the operationalization of the EE1 principle on the macro level. They provide policy targets and a regulatory framework, which impacts the decision-making process of other relevant actors (Heidecke et al., 2021). Thus, the EE1 principle has two functions on the political sphere. Firstly, it can be considered a compass to guide the decision and policymaking process. And secondly, a tool to create a policy and investment environment, which promotes an equal treatment of demand-side and supply-side resources.

A guide to the decision and policymaking process

The initial definition on the EE1 principle stated that the EE1principle requires a commitment to recognizing and treating EE as the first fuel through all policy decision related to the energy market (Bayer, 2015). This means that the EE1 principle is an overarching concept, which should be considered in every policy and decision process related to the energy system (ENEFIRST, 2019). Since the EE1 principle rather resembles a compass in the decision-making process than a specific action, its implementation resembles more a step-by-step approach (Coalition for Energy Savings, 2015; ENEFIRST, 2019). The first step of this process is to systematically consider all resources as potential options. Both supply-side and demand-side solutions need be included to allow for them to be compared on par with each other in the policymaking process. To avoid a preferential treatment in the comparison process, the full value and impacts of the alternatives should be taken into account. This means that the value assessment should go beyond a pure financial analysis and also cover other impacts such as health benefits or reduced energy poverty. Otherwise the negligence of certain benefits or impacts in the assessment can lead to an undervaluation of resources and thus contradict the premise of equal treatment (Scheuer et al., 2016).

Creation of an environment, which promotes an equal treatment of demand-side and supply-side resources

Investment decisions are the point where demand-side resources get created and are used. These decisions are not made in a vacuum but are highly influenced by the political surrounding. Thus, part of realizing the EE1 principle is the creation of an investment and policy environment, which enables and incentives investments in EE (ENEFIRST, 2019). A combination of deep-seated market barriers to end-use EE investments and historic preferences for supply-side

[2] This is also a key element of the Commission recommendations (EU) 2021/1749: http://data.europa.eu/eli/reco/2021/1749/oj.

investments across the policy landscape contribute to a market imbalance in favor of supply-side solutions. The EE1 principle means recognizing the different barriers that prevent the uptake of EE investments and the necessity to overcome those. Hence, both reversing past policies and implementing new measures to overcome market barriers are part of guaranteeing a level-playing field (Rosenow & Cowart, 2019).

Methodology

Development of a theoretical framework

To capture the multiple aspects of the EE1 principle, a multidimensional indicator approach is chosen to assess the degree to which the EE1 principle is adopted by national policymakers. Since the EE1 principle is a relatively recent concept, no theoretical framework on how to measure the implementation of EE1 principle has been developed yet. Therefore, this indicator approach presents a novelty in the context of the EE1 principle. The first step of this process consists of the identification of essential components of the EE1 principle. To establish the relevant components of the EE1 principle, we mainly relied on the definitions and conceptualizations given on the EE1 principle as listed in the "Defining the EE1 principle" section of this paper. The results are the following five dimensions as the base for the EE1 indicator:

- *The EE1 principle in the policymaking process*: The EE1 principle requires the recognition of EE as a flexible input variable in the policymaking process, which should be considered on par with alternative resources (ENEFIRST, 2019). Therefore, the indicator in this dimension assesses the extent to which EE is treated as resources on its own in the policymaking process and how it is compared with other options in this context. This criterion links to the statements "*energy demand is not fixed*" and "e*quality of supply and demand resources*."
- *The removal of market barriers to EE investments*: The core of the concept rests in the equality of supply and demand resources (ENEFIRST, 2019). However, a combination of historic preference for supply-side investments across the policy landscape and of deep-seated market barriers to end-use EE investments often contribute to a market imbalance in favor of supply-side solutions (Rosenow & Cowart, 2019). The EE1 principle means recognizing the different barriers that prevent the uptake of EE investments and the necessity to overcome those. Hence, both reversing past policies and implementing new measures to overcome market barriers are part of guaranteeing a level-playing field. This criterion links to the statement "e*quality of supply and demand resources*."
- *Consideration of challenges to EE*: This category encompasses societal trends and issues, which if they remain overlooked by policymakers might impede or even counteract the purpose of the EE1 principle. This links to the statement "*ubiquity in all energy policies and strategies at any level*."
- *Regional and local adaptation of the EE1 principle*: While the national level presents a good starting point for the introduction of the EE1 principle, the regional and local adaption is essential to guarantee that the EE1 principle is considered in all decisional related to the energy market (EU, 2018). This criterion links to the statement "*ubiquity in all energy policies and strategies at any level*."
- *Monitoring and verification process*: In context of the EE1 principle, a clear and high-quality monitoring and verification process has dual function. Firstly, it allows for more effective and targeted policy interventions. Secondly, monitoring and evaluating of the impact of EE measures provides a base for the quantification of the multiple benefits of EE (Rosenow & Cowart, 2019). This criterion links to the statement "*energy demand is not fixed*."

In combination with the input from chapter 2 and additional literature review, we developed a set of criteria for each dimension. They are chosen in such a way that they capture the core elements of the principle, while at the same time offer the MS the flexibility to apply the EE1 indicator to country-specific circumstances. An emphasis was set on keeping the criteria simple, so that besides presenting an assessment tool, they can easily be used as a guideline or checklist by the MS to

Table 1 Overview of the criteria for the policymaking process

Criteria	Score	Description
Screening process, in which both supply and demand options are compared with each other	0	Demand is considered as a fixed variable in the modeling process
	1	Both supply- and demand-side solutions are considered but separated from each other
	2	Both demand- and supply-side solutions are compared in the modeling process
Comparison between different solutions via cost–benefit analysis (CBA) or other comparison methods (e.g., multi-criteria analysis)	0	No CBA or alike is conducted
	1	CBAs are conducted; however, these do not have an impact on policy decisions
	2	CBAs are conducted and serve as a decision tool between different measures and policies
Discount rates	0	The discount rates differ between supply and demand
	1	The discount rates are similar or the same, but only in a few sectors
	2	Across all sectors, the discount rates are the same or differ slightly
Multiple benefits (MBs)	0	The MBs are neither acknowledged in discussions nor quantified or included in the decision-making process
	1	It is recognized in discussions that EE has positive impacts including social, economic, and environmental aspects. Furthermore, some of those benefits are quantified and incorporated in the decision-making process
	2	The MBs are recognized in discussion as well as quantified (where possible) and included in the modeling approach
Economic efficiency potentials as a guiding principle	0	While economic EE measures might be calculated, they have no significant role during the policymaking process
	1	Economic EE potentials have a guiding function. They are used to identify end-user and sector/areas with large potential as well as support the target setting
	2	EE potentials are used to guide policymakers in their decision process. Additionally, the impact of the chosen policies is compared to the economic EE potential, to ensure that the existing and planned policies are sufficient to exploit the economic potential of EE

facilitate the operationalization of the EE1 principle. In total, the EE1 indicator consists of 13 criteria, whereby the number assigned to each dimension differs.

The following sections describe the five categories and the criteria associated with them. Thereby, Tables 1, 2, 3, 4, and 5 give an overview of the criteria and the corresponding scoring system. The rating of the criteria follows a simple semi-quantitative scoring system, which ranges from 0 to 2. Thereby a score of 0 reflects no or a minimal compliance, while a score of 2 is assigned to MS, which fully meet the criteria and show a high degree of compliance with the criterion.

Selection of criteria to assess the EE1 principles

Policymaking process

The demand for the EE1 principle emerged from the failure of the MS to exploit the economic EE potentials. For this purpose, one main aspect of the EE1 principle is to remind policymakers that energy demand is not fixed and should rather be considered

Table 2 Overview of the criteria regarding the removal of barriers

Criteria	Score	Description
Prevention of distorted markets	0	No concern is given to this issue
	1	Distorted markets are recognized as a concern and current as well as planned policies aim to prevent any market imbalances However, past policies and measures are not actively revised for this purpose
	2	Distorted markets are recognized, and past policies/measure are actively reversed in order to correct those imbalances
Access to information	0	No specific measures regarding information, training, or education campaigns are implemented to overcome informational barriers
	1	While information exists, it is kept in a general format, e.g., on a website
	2	Besides the provision of general information, specific information, and awareness campaigns, energy advice centers or one-stop shops are conducted. Furthermore, more targeted campaigns in form of seminar and trainings offered to a diverse group of actors
Access to capital	0	No concrete measures offer financial support to incentivize EE investments
	1	Financial incentives are in place but limited to certain sectors and instruments
	2	Financial incentives are offered across different sectors and available in form of different instruments, so that a diverse group of recipients can profit from them
Reduction of risk and uncertainty	0	No measures to mitigate the risk for individuals or companies are implemented
	1	Measures to mitigate the risk are introduced for businesses or in the residential sector
	2	Measures to reduce risk are introduced for both businesses and in the residential sector

Table 3 Overview of criteria regarding the challenges to EE

Criteria	Score	Description
Energy poverty	0	Either no policies or solely social policies are aimed at reducing energy poverty
	1	Energy poverty is mentioned in the context of energy policies, but not specifically targeted by any of the EE measures
	2	Energy poverty is incorporated in EE policies, which means that vulnerable households are targeted by the EE measures
Sufficiency	0	No attention is given to this issue
	1	The promotion and relevance of energy sufficiency is discussed
	2	Concrete measures are in place to address and promote energy sufficiency

Table 4 Overview of the criteria regarding the local and regional incorporation

Criteria	Score	Description
EE1 principle on regional and local level	0	The EE1 principle is not incorporated or not wanted on the local and regional level
	1	The status of the EE1 principle is not incorporated
	2	The EE1 principle is incorporated on the local/regional level

next to supply-side solutions in every decision related to the energy system. Therefore, an *approach to include both supply and demand-side solutions* in the policymaking process and target setting presents the first criterion. An example for a policy design, which limits the scope of considered options, is the current policies on the heating sector at the EU level (Heidecke et al., 2021). The Energy Efficiency

Table 5 Overview of the criteria regarding monitoring process

Criteria	Score	Description
Monitoring	0	There are no official guidelines in place. The monitoring occurs unregularly and differs in intensity across sectors
	1	While there are monitoring guidelines in place, they fail to cover all sectors and no regular reports are submitted. Furthermore, the type of monitoring is simplified, for example, by only applying a top-down approach to evaluate the development in EE
	2	Official guidelines are in place. They cover all sectors and require the application of more complex measuring tools, e.g., the use of both top-down and bottom-up approaches; both ex ante and ex post evaluations are used to assess the success the measures

Directive (EED, 2012/27/EU) and its Amendment (2018/2002/EU) currently constitute the two main policies on district heating. While they require the MS to consider all relevant supply resources available within the system, and to identify the most resource- and cost-efficient solutions, it fails to take the full range of potential resources into account. In particular, they neglect to include end-use efficiency such as improved insulation, and the use of demand response in district heating network in the scope of potential investment options. Thereby, this policy design prevents the prioritization of more cost-effective end-use efficiency and demand response investments over the deployment of capital-intensive infrastructure as it is required by the EE1 principle (Heidecke et al., 2021). The implementation of the EE1 principle aims to ensure that during the design of policies, targets, and definitions of regulatory frameworks, all available options are considered and not limited to specific resources.

However, just considering different options in the policymaking process is not sufficient to achieve EE1. To ensure that demand-side resources are prioritized whenever they are more cost-effective from a societal perspective, the different alternatives need to be compared on equal terms with each other. Therefore, the application of a *cost-benefits analysis (CBA)* or *multi-criteria analysis (MCA)* presents a necessary step to guarantee that the chosen alternative presents the most cost-efficient solution for the whole society (Coalition for Energy Savings, 2015). In contrast to other approaches such as the least-cost analysis, the CBA systematically compares both total cost and benefits of the different alternative and thereby goes beyond a pure financial analysis. This allows policymakers to make a decision based on the best value for the whole society (ENEFIRST, 2019). This is particularly relevant in the case of EE due to the MBs, which are associated with improvements in EE (Kavvadias, 2015). The omission of the MBs in the impact assessments of the policy alternatives leads to an undervaluation of EE opportunities and can contribute to an underinvestment as well as to a sub-optimal level of EE from a societal perspective (Thema et al., 2019). The implementation of the EE1 principle is a way to ensure that the full value of demand-side options is considered in all decisions related to the energy market (ENEFIRST, 2019). Therefore, *the inclusion and quantification of the MBs* in the decision-making process presents the third criterion in this dimension.

Besides, a neglect or a selective inclusion of the benefits in the CBA, overestimating the costs of EE resources through inflated discount rates, may also result in a bias against EE (Scheuer et al., 2016). To evaluate the costs and benefits of the energy system from a societal perspective, a societal discount rate should be applied in the policymaking process since it considers the costs and benefits together from the point of view of society as a whole and not from the point of view of a single stakeholder. In the analysis of energy scenarios, the applied discount rate by governmental agencies in the EU is recommend to range between 1 and 7% (Steinbach & Staniaszek, 2015). Furthermore, to avoid biases and to ensure that EE competes on equal terms with supply-side alternatives, the discount rates can differ by sector and socio-economic attributes, but not between different technologies (Steinbach & Staniaszek, 2015).

The discount rates also influence the assessment of *economic EE potentials*, which have two relevant functions under the EE1 principle. Firstly, a guiding function to help policymakers to identify potential end-users and to implement measures accordingly. The revelation and identification of policy

areas, which contain most economic EE potentials, can help policymakers to decide on where to focus and to achieve a high impact through policy interventions (ENEFIRST, 2019). The second function of economic EE potentials under the EE1 principle is a verification mechanism to check if the planned and implemented measures are sufficient to exploit the existing cost-effective EE potentials. The necessity of the EE1 principle is a result of the untapped economic EE potentials across the EU, and hence, the full exploitation of those can be considered as indication for a successful implementation of the EE1 principle.

Removal of market barriers

As described in chapter 2, the EE1 principle aims to remove existing market and regulatory barriers to EE to ensure that demand side resources can compete on an equal footing with supply side ones. Since the EE1 principle is a relatively recent concept, the literature on potential barriers to the implementation of the EE1 principle is limited. Therefore, the selection of relevant barriers is based on the literature on underlying barriers to essential components of the EE1 principle such as barriers to EE and to level playing field for the comparison of demand-side and supply-side resources.[3] Thereby, a focus was to select those barriers, which actively create a bias in the way that EE resources are assessed, valued, and compared with other resources or limit the scope of options considered in the decision process related to the energy market. Furthermore, the selected barriers for this category are connected or can be influenced by governmental institutions, since the indicator in this paper focuses on political actors as the executing agents of the EE1 principle.

An important political barrier, which actively intervenes with the objective of an equal treatment between different resources, constitutes the preferential treatment of supply-side resources. Previous trends in policymaking often prioritized supply-side resources over demand-side solutions, e.g., in form subsidies for fossil energy, bias in public funding which puts supply-side investments before demand-side investments, or regulatory practices. The prevailing imbalance between the different resources is reflected by energy investments in the EU. The review of past policies and measures based on the criteria of equal treatment as well as to reverse those preferential measures is therefore critical to avoid *market distortions* (Rosenow & Cowart, 2019).

Apart from market imbalances, a significant share of EE potentials remains unrealized due to a range of deep-seated market barriers (Rosenow & Cowart, 2019). Part of reaching EE1 is to detect and to overcome those barriers through the implementation of standards and measures. *Imperfect information* has been identified as a potential market failure, which includes not only a lack of information but also deficiencies regarding the quality, trustworthiness, and amount of targeted information. Unawareness or a lack of information on EE opportunities and the benefits associated with such investments significantly impacts the valuation and assessment of EE investments (Wohlfarth et al., 2017). In particular in the building sector, decision-makers are often not aware of the benefits of EE measures compared to renewable energy installations or business-as-usual processes (ENEFIRST, 2020).

Furthermore, limited *access to capital* may deter end-users from investing in EE improving technologies, especially if they rely on external capital for the investment. Since some of EE improvements require high upfront costs and have long period of returns on investments, financial barriers can present a significant burden to end-users. Correspondingly, funding and financial support for buildings has been identified as one of the key pillars to improve EE in the building sector across the EU (ENEFIRST, 2020). For instance, tax incentives and low-interest loans are considered to be important factors to overcome this barrier (UN, 2018).

The fourth barrier considered in this category is the *reduction of risk and uncertainty* connected to EE investments. While every investment decision is associated with certain risks, high implicit discount rates for investments related to EE indicate a particularly high-perceived risk. The underlying sources for the high-risk perception range from uncertainties about future regulations, misperceived technical risk, or

[3] For more information on potential barriers to EE, see, for example, Brown (2001); Schleich (2009); Thollander and Palm (2013).

production interruptions (Schleich, 2009). Concerns about reliability, possible production disruptions, and high maintenance costs pose obstacles and might lead investors to overestimate the technological risk. Policies can provide regulatory stability, lower the financial risk, and reduce the perceived technological risk by supporting the exchange of experiences and knowledge between the different actors to reduce the risk associated with the introduction of new technologies.

Challenges to EE

The challenges to EE encompass societal issues and trends, which might impede the realization of the cost-effective EE potentials, if policymakers fail to address them. The first obstacle constitutes *energy poverty* and is related to the need to overcome barriers as outlined in chapter 3.1.2. Many of the market barriers to EE affect energy poor household to a greater extent compared to the wealthier parts of the population (EP, 2016). For instance, informational barriers like a lack of awareness and knowledge of the own energy consumption, on energy saving potentials in their dwelling, and on the multiple benefits associated with efficiency improvements tend to be more prevalent in energy poor households. In a similar manner, energy poor households are confronted with aggravated economic barriers like higher risk and greater financial barriers (EP, 2016; Ordonez et al., 2017). The consideration of the circumstances of vulnerable households in the design of policies is necessary to ensure that the whole population is able to implement EE intervention and that the economic EE potentials are realized. Furthermore, the neglect of energy poverty in the context of energy policies and its exclusive treatment with social policies like energy payment assistance for low income housholds (e.g., Chèque énergie in France) might even disincentive energy efficient behavior and thus contradict the EE1 principle (EP, 2016).

The second challenge is related to *energy sufficiency*, which can be defined as a state in which peoples basic needs for energy services are met equitably and ecological limits are respected (ECEEE, 2018). Thereby, this challenge deals with cultural factors, which influence the mindset and thinking of the relevant actors. Those behavioral aspects and attitudes are highly influenced by societal trends and can both support and contradict the aspirations of EE. For instance, the conception that consumption is a sign of wealth and status can lead to a raising number of electric appliances and increase the demand for larger dwellings. This in turn increases the energy demand and thus counteracts EE gains. On the other hand, energy sufficient behavior such as a more conscious consumption of meat and less air travel can have the opposite effect (Förster et al., 2019). The implementation of measures addressing and promoting energy conservation attitudes such as energy sufficiency can prevent negative societal trends such as the use of larger cars to unfold in unmanaged manner and thereby the creation of new inefficiencies in the energy consumption. For instance, a study on different policy scenarios showed that implementing strict policies and measures across the EU to accompany new societal trends related to the digitalization of life, industrial transformation, quality and life, and general changes in the social and economic models can lead to energy savings of 376 Mtoe by 2050 (Brugger et al., 2021). Since the discussion around sufficiency is still in its early stages and energy poverty already an established issue, the requirements of the scoring system are less demanding for sufficiency.

Integration of EE1 on different levels

One key element of the EE1 principle is its ubiquity. The Governance Regulation explicitly states that "Member States should also encourage the spread of that principle in regional and local government, as well as in the private sector" (EU, 2018/1999; Recital 64). The adoption of the EE1 principle on all governmental levels as well as in the private sector is a way to guarantee an equal treatment of supply- and demand-side resources and ensure that EE comes first throughout the whole energy system (EU, 2018). The exact role and competences of the regional and local governments differ across the MS. However, with remits like spatial planning, overseeing the heating infrastructure or individual target setting, the decisions of those entities have a great impact on the energy system. Furthermore, private entities like banks play an essential role in financing energy investments (EEFIG, 2015). However, since in this paper the focus is on political actors as the executive agents of the EE1 principle, the criterion in this category is limited to the implementation of the EE1

Table 6 Overview of the interviewed stakeholders

	AT	DE	DK	ES	FR	IE	IT	LT	LV	MT	NL	PL	SE	SI
Questionnaire					X		X			X				
Interview	X	X	X	X		X	X	X	X		X	X	X	X
No. of stakeholders	1	1	1	4	1	1	2	2	2	1	1	2	1	2

by public institutions on every level. Regional and local authorities are close to the end-user and often act as implementation agents, planner, consumer, supplier, or advisor. They are involved and able to influence many decisions related to the energy market (Dobravec et al., 2021). Therefore, to ensure a successful implementation of the EE1 principle and the effectiveness of measures, an active participation of all governmental entities is required.

Monitoring and verification of energy efficiency trends and policies

Part of the EE1 principle is the establishment of clear *monitoring and verification standards* regarding energy efficiency trends and policies. Access to data and information on the progress of energy savings and the success of EE measures allows the MS to review their strategies continuously and adjust the design of their measures. For instance, the detection of unsuccessful information campaigns or a slow uptake of loans gives policymakers the opportunities to adapt their measures early on. This in accordance with global experiences, which imply that active oversight and continuous programme improvements are needed to uncover and deliver on demand-side potentials in almost every market (Rosenow & Cowart, 2019). Furthermore, periodical reviews and the collection of data on the impact of EE measures improve the quality of the CBAs. Impact evaluations on the economic, environemtnal, and social benefits facilitate the inclusion and quantification of the MBs in the decision-making process and hence consitute an essential component of the EE1 principle (Coalition for Energy Savings, 2015).

Data sources

In this paper, the operationalization of the indicator is tested through an assessment of the degree to which 14 MS have incorporated the EE1 principle in the development of the NECPs. The NECPs were introduced under the regulation on the governance of the energy union ((EU), 2018/1999). They require each MS to outline a plan, on how they intend to reach the national and European energy and climate goals, starting from 2021 until 2030. Apart from the specific targets set by the Clean Energy for All Europeans package, the MS have to address the five dimensions defined under the Energy Union strategy: research and innovation, market interconnectivity, decarbonizing the economy, EE first, and energy security (European Commission, 2020). Thereby, the importance of and the necessity to apply the EE1 principle in the NECPs is emphasized in the regulation on governance: "*With regard to their integrated national energy and climate plans, Member States shall (…) take into account the interlinkages between the five dimensions of the Energy Union, in particular the EE first principle*" (EU, 2018, p. 56); however, no specific guidelines were provided by the Commission at this point.

In this paper, two main sources of data are used. The first part of the evaluation consists of semi-structured interviews, which we conducted with stakeholders that were either directly involved in the preparation of the NECP or participated indirectly in form of advisory activities and have a comprehensive understanding of policymaking process in the MS. As the second source, NECPs and the ODYSSEE-MURE database were used.

Since the interviews are necessary to get an understanding of the decision- and policymaking process during the preparation of the NECPs, the application of the EE1 indicator is limited to MS, where we were able to make at least one interview.

Table 6 provides an overview of those MS and shows the number of stakeholders interviewed per country.

Since the main aim of the assessment is to test whether the indicator is applicable across different countries in the EU, the limited number of interviewees per country does not present a concern to the purpose of this paper. However, it should be stated that for this reason, the result on the degree to which the MS have implemented the EE1 principle in the

development of the NECP should be considered with caution. Also because the NECPs were prepared while no clear guidance on EE1 was available, and the concept was still very new to most policymakers at that time. Such guidance is now provided by the Commission after composite indicator approach presented in this paper has been developed.

In total, 14 MS were selected for the interviews. The selection is based on three criteria: geographical coverage, size of the country, and performance in EE. Since climate and economic development impact energy demand and consumption patterns, the geographical selection criteria focused on the inclusion of countries in different climate zones and of different economic power (Huang et al., 2021). Smaller countries (e.g., Malta and Slovenia), medium size countries (e.g., Austria and Italy), and larger countries (e.g., France and Spain) are part of the sample due to dependency of energy demand on the size of a country and the personnel capacities of the countries. The third selection criterion is the general performance of countries regarding EE. To include a diverse set of countries, we relied on the EE scoreboard from ODYSSEE-MURE (ODYSSEE-MURE, 2020). The scoreboard ranks the countries and assigns a score to each of them based on their level of EE, EE trend, and EE policies. Similar to the other two selection criteria, countries at the bottom, at the top, and in the middle of the ranking are chosen.

In course of the interviews, various areas of the policymaking process and the NECP are discussed. To ensure that the respective stakeholders with expertise on our question are present during the virtual interviews, we sent out questions to our partners beforehand. This allowed our partners to self-select the relevant interviewees for our request in advance. Most respondents work at national environmental, energy, or infrastructure agency and thus had a comprehensive understanding on the underlying development process of the NECPs. Furthermore, we interviewed experts from research institutions such as universities and public research bodies and consultancies, which worked as advisors for governmental entities involved in the preparation of the NECPs. Figure 1 provides an overview of share of interviewees, who work for the different types of organizations.

The stakeholders had the option to answer our questions in course of an interview or a written format. Overall, we conducted 12 interviews, which involved 1–4 interviewees at the same time, and sent out three questionnaires. While for most countries one single format was chosen, we conducted both an interview and sent out a questionnaire to assess the EE1 principle in NECP of Italy. Both formats consisted of 13 predefined questions on the 13 criteria. To ensure that we received the relevant information from the interviewees, we included follow-up questions or requested more elaborated answers. In addition to that, we examined the NECPs and used the ODYSSEE-MURE (ODYSSEE-MURE, 2020) database to gather additional information on the measures and policies, which address the financial and informational barriers as well as the reduction of risk associated with the investments in energy efficiency. In case of contradictions between the interviews and the NECPs, the results from the NECP are used in the evaluation.

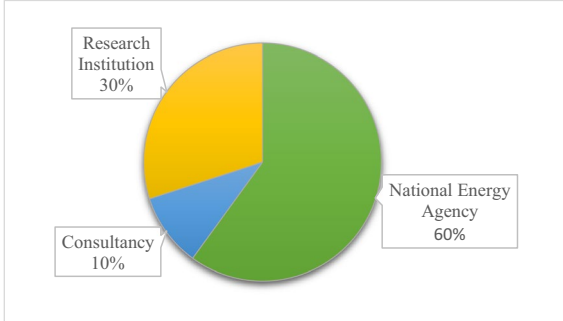

Fig. 1 Type of organizations the respondents work for

In the case of missing values due to the inability of the stakeholders to answer certain questions or the inapplicably of a question to the circumstances of the country, the missing inputs are replaced by using an unconditional mean imputation (OECD, 2008). However, in case of more than two missing responses for one country, the country would be excluded from the dataset.

Methodology of the composite indicator

To assess the EE1 principle across the 14 MS, we constructed a composite indicator. This is an established tool for assessing and ranking countries in terms of sustainability, human development, competitiveness, or other complex phenomena, which are not

Table 7 Weighting scheme of the indicator

Category	Criteria		Level of priority	Weight
Policymaking process	1	Comparison of supply and demand	High	2.0
	2	Cost–benefit analysis	High	2.0
	3	Discount rates	High	2.0
	4	Multiple benefits	High	2.0
	5	Economic efficiency potentials	Medium	1.5
Market barriers	6	Prevention of distorted markets	Medium	1.5
	7	Access to information	High	2.0
	8	Access to capital	High	2.0
	9	Risk and certainty	Low	1.0
Challenges	10	Energy poverty	Medium	1.5
	11	Sufficiency	Low	1.0
Regional and local level	12	Region and local level	Low	1.0
Monitoring	13	Monitoring	Medium	1.5

easily measurable and uniquely defined (Becker et al., 2017). The approach provides the simplicity required to facilitate the evaluation and comparison of the multiple aspects of EE1 principle.

As previously stated, in each category, the MS receive a score ranging from 0 to 2, whereby 2 represents a full compliance with the criterion and 0 the opposite. This scale is applied to all categories and thus, no additional normalization method has to be applied to the individual indicators. Afterward, the individual scores of the criteria are aggregated into a single indicator. For this purpose, a linear aggregation of the weighted criteria is applied. The result is the following formula to describe the performance of countries regarding the adoption of the EE1 principle:

$$y_j = \sum_{i=1}^{13} w_i x_{ji} \quad i = \text{index of the criterion} \quad \text{j: country}$$

With;

y_j value of the indicator for country j

w_i weight of the criterion i

x_{ji} score of the criterion i for country j

The summation of the weighted and, if necessary, also normalized individual indicators is the most widespread linear aggregation methods. This approach allows for some degree of compensability between the different individual indicators (OECD, 2008). This means depending on the weights, the MS can compensate a deficit in one category or criteria with a high performance in other criteria. The weights differ between 1, 1.5, and 2 and reflect the degree of priority in realizing EE1, which is assigned to each criterion. The result is an indicator with a maximum score of 42 and minimum score of 0. Table 7 displays all 13 criteria including their weights.

Overall, the criteria are assigned a low, a medium, or a high weight. The weighting process started with the assumption that all criteria are equally important and thus of medium priority. In a second step, we evaluated every single criterion against literature research from chapter 2 and chapter 3 and from that derived its relevance to the realization of the EE1 principle. The findings of this evaluation were that in total eight criteria can be considered to be conditional to achieve a full implementation of the EE1 principle. On the other hand, three criteria can be considered to be of lower relevance to the EE1 principle at this point in time. The residual four criteria remain at medium priority, since they are fundamental to the principle, but are not directly linked to the core requirements of the EE1 principle. The following paragraphs briefly explain the reasoning behind the high and low priority criteria.

Firstly, the criterion about the comparison of supply- and demand-side resources addresses the core idea of the EE1 principle, which is to encourage policymakers to consider EE resources next to

supply-side alternatives in their decisions related to the energy market. To guarantee an equal treatment and thus ensure the quality of the comparison, the fulfillment of three further criteria is necessary. Therefore, we also assigned a high value to CBAs, discount rates, and the MBs since these factors influence the attractiveness of EE investments, the necessity of EE measures, and the overall target setting. As the exploitation of the EE potentials requires the removal of barriers, both the provision of capital and information also belong to the group of high priority criteria.

In total, three criteria are of lower priority due to different underlying reasons. Although the EE1 principle requires its implementation on all levels, we assigned a lower value to the regional and local integration. We acknowledge that the implementation of the EE1 principle across all governmental level is imperative to ensure that EE comes first across the whole energy system and the effectiveness of EE-related measures. However, the focus lies on its operationalization on the national level, which might be followed by a diffusion of the application of the principle to other levels. Similar reasons are behind the low priority associated with sufficiency, which is not a focus of the EE1 principle in general, but might help to increase energy efficiency progress. The third criterion, which we assigned a low priority, involves the implementation of measures to target the reduction of risk and uncertainty surrounding EE investments. This decision is based on its overlap with the criterion of access to finance as financial support can also present a form of risk reduction.

Due to the use of a linear weighted combination in the construction of the EE1 indicator, the weights determine the degree of compensability between the individual criteria. Therefore, the aim of the weights is to produce a total performance score, which is significantly higher for countries with a high performance in the high priority criteria. This means countries get a higher total score if they comply with core criteria of EE1. On the other hand, the distance between the different weights should not be so large that the medium and lower weighted categories become irrelevant. This means that a good performance in the high priority criteria cannot completely offset deficiencies in the medium and lower weighted criteria. The result is the weighting scheme as described in Table 7.

Results

This section provides an overview of the state to which extent the EE1 principle is implemented in the development of the NECPs by the MS based on the information collected for this pilot assessment. However, as stated previously, the results should be considered with caution due to the limited number of interviewees and the scope of interviewees involved in the assessment. In addition, the fact that EE1 principle was first introduced in 2016 and first defined in the Governance Regulation of the Energy Union only late 2018 means that it was still a relatively new concept to the stakeholders involved in the NECP process in the Member States. In Fig. 2, the 14 MS examined in this paper are highlighted in color and provide a first impression of the degree of operationalization of the EE1 principle.

The highest total score reaches Ireland with a score of 31.5 out of 42, which means that in development of the NECP Ireland fulfills 75% of the criteria included in the indicator. Further four countries — Spain, Malta, the Netherlands, and France — have a score above 20 and the remaining countries range between a score of 17 and 19.

EE1 principle in the policymaking process

To assess the EE1 principle in the policy and decision-making process on the national level, we developed five criteria, whereby four of those are considered to be of high priority. Figure 3 lists those five criteria and illustrates the extent to which the 14 MS comply with each of them in the NECP based on the information collected for this pilot assessment.

The criteria, in which the MS show the greatest deficiencies, are the *discount rates*. Around 64% of the analyzed MS received the lowest score for their use of the discount rates. The low score either reflects the application of significantly different discount rates for supply-side and demand-side investments or a lack of including them in general. Although Latvia also applied different discount rates in the development of their NECP, they reached a score of 1 as the deviation between the resources is less than 5 percentage points.

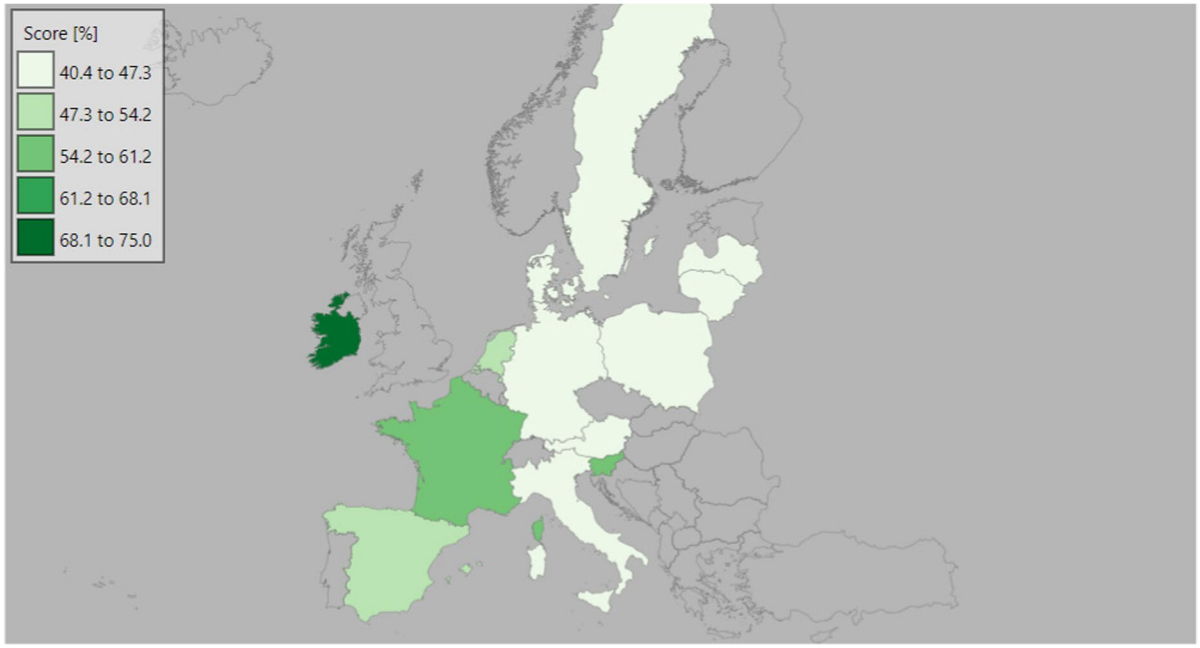

Fig. 2 Implementation of the EE1 principle in the NECPs

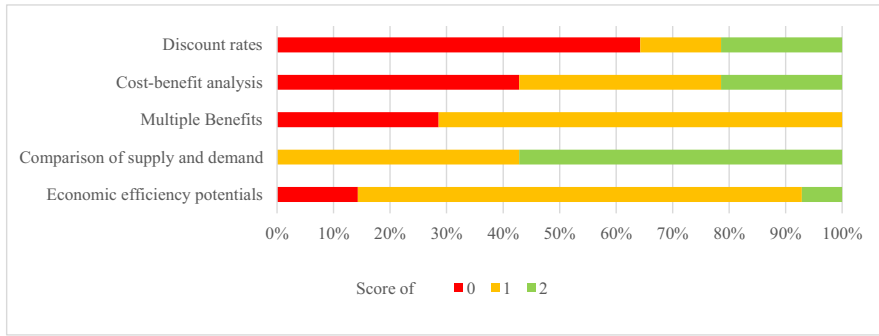

Fig. 3 Results of the 14 MS for the implementation of EE1 principle in the policymaking process within the NECP

A score of 2 was assigned to Ireland, the Netherlands, and Austria as they applied the same discount rates irrespective of the program, resource, or sector.

Among the MS, only Ireland, Slovenia, and Sweden conducted *CBA*s to compare different measures with each other, in particular supply-side and demand-side solutions. This means that 21% of the interviewed MS successfully incorporated this aspect of the EE1 principle in their policymaking process. However, with 42%, most of the MS received a score of 0 as they use other methods to compare the different alternatives with each other, which do not consider a broader review of costs and benefits of the options available. The minimization of costs guided the development of the NECP in Spain, Latvia, and Denmark. In Germany and Austria, neither the costs nor the benefits determined the selection of measures. Instead, political factors, federal competencies, and the ability to promote certain measures influenced the comparison. In Germany, CBAs were still conducted, however not for the purpose of comparison, but rather to assess the impact of the selected measures afterwards. The MS, which received a score of 1, applied a CBA to some extent, but not in every comparison. For instance, Lithuania uses CBAs to directly compare measures, but within their forecasting models the least cost-principle dominates.

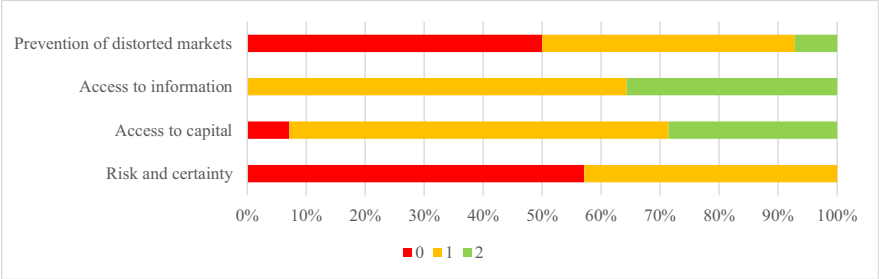

Fig. 4 Results of the 14 MS for the removal of barriers to EE investments within the NECPs

Regarding the recognition and quantification of the *MBs* of EE in the NECP, with 71% most countries received a score of 1. While these countries recognized that the benefits include environmental, economic, and social benefits, they focused the quantification to the reduction of emissions and economic aspects like GDP growth and job creation. Latvia and Spain additionally include air pollution and quality as possible benefits in their calculation. Overall, no MS included and quantified a broader set of MBs, which covers several aspects of economic, social, and environmental impacts. A score of 0 was assigned to the Netherlands, Slovenia, Germany, and Austria. The Netherlands exclusively looked at environmental benefits in form of lower emissions, which is in accordance with their political focus on the reduction of GHG emissions. Furthermore, in Germany and Austria, the MBs are solely taken into account in qualitative manner within discussions.

Regarding the equal treatment of *supply and demand-side solutions in the screening process* for policies and measures, the MS on average performed the best. Each MS at least considers EE as viable resource to meet a range of targets and requirements. For the development of the NECP, 64% of the MS based their decisions on energy models, which consider both supply- and demand-side options across all sectors and target areas. While Denmark also treats EE as a resource on its own, it evaluates EE and renewables or other supply-side options separately from each other. A similar approach is taken by Malta, who treat EE as a priority in a variety of areas but assess supply- and demand-side alternatives in a separate manner. Therefore, both Denmark and Malta as well as Sweden, Germany, and Lithuania receive a score of 1 in this criterion.

Economic EE potentials present the last criterion of this category. As described in chapter 3, the economic EE potentials function as a guide as well as a benchmark under the EE1 principle. Figure 3 demonstrates that the majority of interviewed MS reached a score of 1 and thus solely made use of one of the functions. These countries used the economic EE potentials as a base of the energy models and scenarios and used them for identification purposes. However, a direct comparison with the impact of existing and planned measures is solely carried out by Ireland and Malta.

Removal of barriers to EE investments

This category contains four criteria, whereby two of them are of high priority, one of medium priority, and one of low priority. Figure 4 provides an overview on how the countries in total performed in each category based on the information collected for this pilot assessment. Overall, the majority of MS received a score of 1 in each criterion, which implies that across the EU, the requirements of those categories are mostly met at a moderate level.

In regard to the prevention of *distorted markets*, only France systematically reviews existing imbalances and corrects those by adjusting or reversing past policies and measures. Another 42% of the MS commit to avoid possible imbalances through present and future policy decisions. In total, half of the interviewed countries fail to address this concern in their NECPs. Denmark recognizes imbalances, in particular between renewables and EE, but does not consider it to be an issue as the GHG emissions are not affected by this. Further countries with no systematic approach to market distortions are Poland, Spain, Germany, Malta, and Ireland.

Another obstacle to investments in EE presents a *lack of information*. All interviewed MS acknowledge the relevance of information and include at least

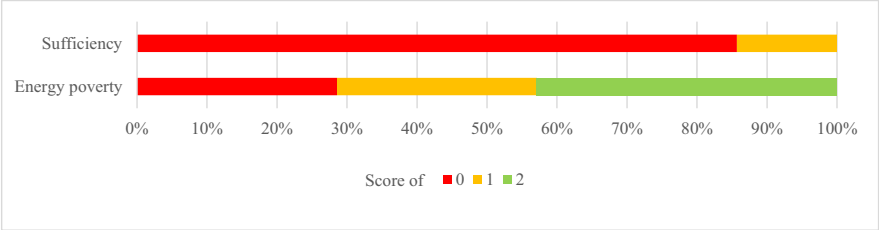

Fig. 5 Results of the 14 MS for the treatment of the challenges to the EE1 principle within the NECP

general measures to provide information to consumers and investors. Thereby Ireland, Spain, Denmark, Germany, and Malta reached a score of 2 for this criterion as they differ from the other countries in terms of the degree of targeted information, the sectors covered by information programs, and the variety of measures offered. This contrasts with the remaining 64% of MS covered by this paper, who have implemented some information programs like general awareness campaigns and the provision of free or subsidies energy counseling services in the NECP but keep them in a general format and cover a limited number of consumers.

Access to capital is an essential criterion to facilitate the necessary investments in EE. Similar to the informational barrier, with 64%, the majority of countries show a moderate effort to overcome this barrier and thus receive a score of 1. One of these countries is Denmark, whose NECP contains subsidy schemes for the residential sector and grants aimed at private enterprises but exclude the transport and service sector from any financial support regarding EE investments. Further countries with a score of 1 are Poland, Italy, Slovenia, Latvia, Lithuania, France, Spain, Sweden, and Austria. A score of 0 was assigned to Malta as the financial support is limited to low-income households and the promotion of electric and hybrid vehicle through grants, which have experienced low uptake. The remaining MS Germany, Slovenia, Ireland, and the Netherlands reached a score of 2 due to the variety of financial instruments in the different sectors.

With 57%, the majority of interviewed MS relies on loans and grants to reduce the *risk and uncertainty* related to EE. While financial measures constitute instruments to reduce economic risk associated with EE investments, within the scope of this indicator, they are counted under the previous criterion. This is due to the fact that risk as a relevant barrier, which merits policy intervention, rather refers to regulatory and misperceived technical risk instead of business and financial risks, which are part of economic efficient behavior and present a general issue in regard to investments. Therefore, those eight countries received a score of 0 for their performance and the remaining six MS a rating of 1. Although Slovenian and Latvia also focus on financial aspects, they go beyond loans and grants and introduce guarantee schemes to reduce the risk for EE investments. Furthermore, Slovenia establishes a shared-incentive scheme between owners and tenants in the residential sector and actively promotes new EE technologies to avoid the overestimation of the technological risks associated with EE improvements. In Ireland, the creation of learning networks and cooperation between the largest industries proofed to be an effective way to reduce the risk perception of the quality and reliability of different energy efficient technologies.

Challenges to EE

Figure 5 illustrates that *sufficiency* is not yet addressed by specific measures and represented in the NECP based on the information collected for this pilot assessment. The MS predominantly acknowledge the relevance of sufficiency and include it in internal discussion; however, this has not manifested into concrete measures and policies. Malta and Denmark received a score of 1 in the evaluation as they at least address the topic in the NECP, even though it is only in an indirect manner. Denmark recognizes behavioral aspects as obstacle to EE but has not included any concrete measures. Malta does not directly mention sufficiency, but addresses lifestyle changes like car sharing, which lower the energy consumption.

Compared to sufficiency, the challenge of *energy poverty* receives more attention across the EU. However, not every country, which recognizes energy poverty as a concern, addresses this topic in form of EE policies. Denmark, Germany, and

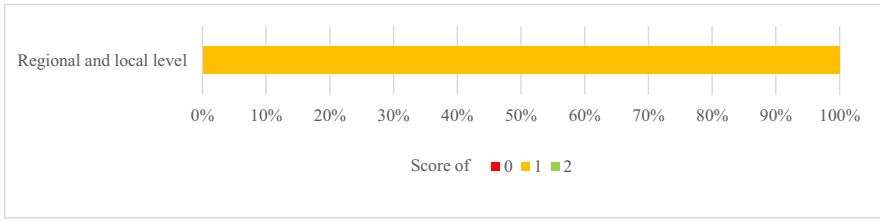

Fig. 6 Results of the 14 MS for the regional and local level implementation of the EE1 principle within the NECP

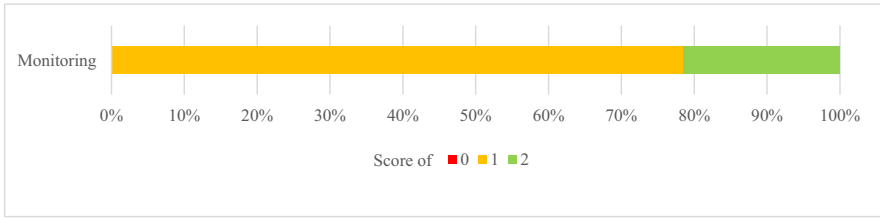

Fig. 7 Results of the 14 MS for the monitoring of EE within the NECP

Malta treat energy poverty in the scope of social policies, which rather focus on financial support for energy bills and heating than reducing the bill through EE improvements. Other countries incorporate energy poverty in their energy policies, but do not necessarily target vulnerable or low-income households in this context. For instance, Lithuania lists three different EE measures to reduce energy poverty, but none of them is targeted measures. Latvia also follows this approach of general EE policies to combat energy poverty, which resembles a score of 1. The countries with a score of 2 are Spain, France, the Netherlands, Austria, Ireland, and Slovenia. In those countries, the EE measures in the residential sector contain higher aid intensities for vulnerable or low-income households and thus target energy poverty specifically.

Support to the implementation of EE1 principle on the regional level

Regarding the implementation of the EE1 principle on the *regional and local level*, the performance of all 14 MS rank at a score of 1 as illustrated by Fig. 6. All countries support the operationalization of the EE1 principle on all levels of the society; however, no official documents or statements commit to this plan based on the information collected for this pilot assessment. While through top-down mechanisms national targets demand certain actions on the local level and through the participation in national funding-programs, municipalities and regional entities are obliged to follow certain EE requirements, and no clear guidelines for the EE1 principle on the regional and local levels are established.

Monitoring and verification of energy efficiency trends and policies

Similar to the previous criterion, the majority of MS received a score of 1 for their *monitoring and verification* approach. The MS have in common that the monitoring of measures is an obligation and strictly regulated within the NECP. The monitoring process and methods usually vary across sectors and program. The deficiencies in the criterion are related to an insufficient coverage of all sectors and the application of simplified methods such as a sole reliance on top-down monitoring to track energy savings across the economy. Denmark, Latvia, and the Netherlands achieve a score of 2 by combining different measurement approaches and prescribing their application across sectors and programs. The monitoring of policy programmes and their performance is integrated in the national reporting and reviewed on an annual basis. Both bottom-up and top-down approaches are applied across the economy and in combination with historical data, the changes and trends in the different sector are closely monitored (Fig. 7).

Table 8 An assessment of the EE1 principle across the NECPs

Category	Criteria	AT	DE	DK	ES	FR	IE	IT	LT	LV	MT	NL	PL	SE	SI
Policymaking process	Comparison of supply and demand	2	2	1	2	2	2	2	1	1	2	1	2	1	2
	Cost–benefit analysis	0	0	0	0	1	2	0	1	0	1	1	1	2	2
	Discount rates	2	1	1	0	1	2	0	0	1	0	2	0	1	1
	MBs	0	1	1	1	1	1	1	1	1	1	0	1	1	0
	Economic efficiency potentials	0	1	1	1	1	2	1	1	0	1	1	1	1	1
Removal of barriers	Prevention of distorted markets	0	0	0	1	2	0	1	1	1	0	1	0	0	1
	Access to information	1	2	1	2	1	2	1	1	1	2	1	1	1	1
	Access to capital	1	2	1	1	1	1	1	1	1	1	1	1	1	2
	Risk and certainty	0	1	1	0	1	1	1	1	1	0	0	0	1	1
Challenges	Energy poverty	2	0	0	2	2	2	1	1	1	2	0	1	0	2
	Sufficiency	1	0	1	1	0	1	0	0	0	1	0	0	1	0
Regional and local level	Region and local level	1	1	1	1	1	1	1	2	1	1	2	1	1	1
Monitoring	Monitoring	1	1	2	1	1	1	1	1	2	1	2	2	1	1
Total weighted score	Absolute	17.5	17	17.5	20.5	23	31.5	17	17	17	18	21	17.5	19	23.5
	Percentage	42	40	42	49	55	75	40	40	40	43	50	42	45	56

Summary

Table 8 summarizes the results of the previous chapter including the specific scores, which were assigned to the MS for each criterion based on the information collected for this pilot assessment. According to the indicator, on average, around 47% of the aspects regarding the EE1 principle were considered and applied in the NECPs by the MS. The discrepancies between the countries are limited to 35 percentage points, with the best performance at 75% and the lowest one at 40%. Regarding the compliance with single criteria, Figs. 2, 3, 4, 5, and 6 of the previous section illustrate that the extent to which the MS fulfill the requirements differs significantly across categories and criteria.

The first category about the integration of the EE1 principle in the policymaking process consists of four criteria with high priority and therefore has much weight in the overall assessment. The fact that all MS consider EE as a resource on its own and not as a fixed variable in the energy equation means that the most fundamental element of the EE1 principle is understood and implemented by all MS. The fact that the consideration of energy demand as a variable parameter is not self-evident and is partly the result of recent developments is reflected by the energy policy of Poland. Around 5 years ago, Poland still considered energy demand as given and the aim of their energy models was to find supply-side solutions to satisfy the demand. After making EE part of the equation, the second cornerstone of the EE1 principle is to treat EE on par with other resources. According to the results, the majority of MS fail to compare the different options on equal terms with each other. This becomes apparent with respect to the low performance in the three categories CBA, MBs, and discount rates. Some countries do not perceive CBAs to be necessary as they intent to achieve certain targets with minimal costs and without taking any further benefits into account. While this approach helps to ease the strain on the public budget at least in the short term, e.g., through lower subsidies, it may lead to countries to neglect solutions, which in the mid- and long-term present the least costs to the society due to the range of benefits associated with them. Nevertheless, the interviews suggest that the majority acknowledge the relevance of CBAs but are confronted with obstacles regarding the execution. The complexity and difficulty to quantify the benefits was stated as a common challenge by the MS. In particular, social benefits like improved living comfort, health benefits, and the alleviation of energy poverty are hardly mentioned and quantified in the NECPs. Only four countries — Spain, Ireland, Poland, and Latvia — actually recognized health benefits related to EE and the intention to quantify improvements in living comfort was only declared by Ireland. Regarding health benefits, Ireland, specifically noted the inability to quantify and thus provide solid evidence on them, impeded them to fully incorporate health aspects in the policymaking process. In order to solve this issue, they aim to generate more data and evidence on this relationship through a range of pilot projects. On the EU level, the MICAT project exactly addresses this issue through the development of a calculation tool, which provides the MS with a comprehensive approach to estimate the MBs of EE (EC, 2020). Overall, the collection and availability of data on EE as well as on the wide-ranging impacts will be the key when it comes to ensuring the quality of the CBA and the inclusion the MBs in the future comparisons.

A condition for the EE1 principle to prosper and reach its full effect is the removal of any barriers and hurdles to EE investments. Among the four criteria developed for this purpose, a special weight is put on the support to overcome informational and financial barriers. The results imply that the MS share this sense of priority as they have all implemented information programs and financial support measures to incentivize EE investments. However, in the matter of information, improvements can still be made in terms of more targeted information and regular evaluation of the programs, to ensure that the information campaigns are effective and reach the intended cohorts. This in accordance with experiences in Ireland, where the evaluation of national information and awareness campaigns indicated a low effect of general campaigns. As a consequence, they are currently developing more targeted information programs to better reach potential investors and consumers. While few MS are cautious of avoiding imbalances between supply- and demand-side resources in their current policymaking, no concern is given to the review and adjustment of past regulations and systems across the national policy landscape. The underlying reason for this neglect varies across countries. For instance, in

Austria, the spread of competencies across different departments and institutions as well as the federal structure impede the detection of imbalances. Denmark recognizes imbalances, in particular between renewables and EE, but does not consider it to be an issue as the reduction of GHG emissions is not affected by this. In a study about the EE1 principle in the UK, Rosenow et al. (2017) outline the importance of actively reversing historic preferences in the policymaking. They demonstrate this through concrete examples like the National Infrastructure Plan, in course of which 256 billion £ were spent. However, none of the fund was allocated towards efficiency projects due to the neglect of considering buildings as part of infrastructure and EE as an infrastructure priority. This shows that even though this might present a complex task, which is aggravated in case of shared responsibilities and competencies across different institutions and federal entities, the review and adjustment of past measures is nevertheless a necessary step for the creation of a level-playing field.

Besides the removal of barriers, the EE1 principle also requires policymakers to engage with societal trends and other factors, which might counteract the EE endeavors. Within the scope of the indicator, we identified energy poverty and sufficiency as relevant challenges to the success of the EE1 principle. Around one-quarter of the MS focus on social policies to combat energy poverty. While income assistance or direct support via payments of energy bills has the potential to deliver short-term relief, it cannot solve energy poverty in the long-term and simultaneously presents a great financial burden to the public budget. In contrast, targeted EE policies directly address the root cause of energy poverty and therefore can alleviate it in the long-term (Ordonez et al., 2017). Furthermore, governmental payments of the energy bill might even counteract the ambitions of EE since they reduce the incentive for the consumer to reduce the energy bill with EE measures. Besides those few exceptions, the interviews show that energy poverty is considered by the majority of policymakers in the context of EE policies and merely needs more targeted policies at low-income and vulnerable households for all countries to fully address this issue. This is not the case for sufficiency, which is not mentioned formally in any NECP. The interviews indicated that the concept of sufficiency has not fully reached the political sphere and has to be further developed and disseminated, in order for a serious discussions and concrete measures to emerge around this issue.

In order for the EE1 principle to be reflected in all policymaking and investment decisions across the energy system, a criterion regarding its incorporation on the regional and local level was included in the indicator. The interviews delivered two important insights on this issue. Firstly, there is general challenge of forwarding requirements to a subordinate level due to the degree of independence, which the federal states and municipalities enjoy. Furthermore, energy policies and strategies partly differ between the federal states or municipalities and thus, it is difficult to get them to agree on a uniform adaption of the principle. Thus, governmental structures across each MS and the degree of cooperation between the different levels of authority impact the implementation of the EE1 principle on the local and regional level. Secondly, the lack of a clear understanding and guidelines on the EE1 principle on the national level hinders the transmission of the principle to other entities. This is in support with the efforts of this paper to provide the MS with an indicator, which can be used as a guideline for the operationalization of the EE1 principle.

While all the interviewed MS provide a minimum standard of monitoring and verification process in the context of EE, there are still deficiencies in respect to quality of the monitoring method and the coverage of sectors and programs. The failure of only doing ex ante assessment and not to continuously monitor the progress of measures and programs prevents governments from improving programs and making course corrections, which are necessary for the demand-side potential to be exploited (Rosenow et al., 2017). Furthermore, as stated previously, the collection and aggregation of data on EE is essential for the understanding and quantification of the MBs and thus the quality of the CBA.

Discussion

Before drawing an overall conclusion on the application of the EE1 principle in the NECPs, the framework of our indicator approach should be taken into account as it comes with some limitations. The first possible shortcoming stems from the weighting scheme of the individual indicators. Although we

have allocated the weights to the best of our knowledge and the resources available, some assumptions may be affected by subjective judgement. Second of all, our data sources were limited to the NECPs, the ODYSSEE-MURE database, and interviews, which were conducted with 1 to 4 stakeholders per country. These sources can be considered to be sufficient for the acquirement of necessary information about the policies and measures, which are in place to remove market barriers and combat the challenges to EE. Since this information is formally documented, subjectivity presents no concern in this context. In contrast, the assessment of the EE1 principle in general policy- and decision-making requires insights about the policymaking process, which are not necessarily formally and publicly documented. While we chose interview partner with a comprehensive understanding of the policymaking processes in the respective countries, the small number of interview partners per country might introduce some subjectivity to the assessment. In addition to the data weaknesses, it should also be reminded that the concept of the EE1 principle was still relatively new for the stakeholder involved in the development of the NECP since it was first published in a Governance Regulation of the Energy Union by late 2018. Therefore, the result might significantly differ for the next update on the NECPs, which is planned for 2023–2024. Furthermore, in future analysis, the Commission's NECP assessments could be included as a data source to develop and improve the indicator and its use. This would also add further value of the proposed indicator-based approach.

However, overall, the potential shortcomings do not interfere with the purpose of this paper. The aim was to develop an indicator based on a set of criteria, which is applicable across different countries and can support the MS in making the EE1 principle operational. The 13 criteria capture most of the relevant elements of the EE1 principle and aim to provide a comprehensive picture on how the MS treat EE in their policymaking and target setting. However, regulatory frameworks are not covered in this set of criteria yet. Future improvement of the indicator could also include the coverage of the way regulatory frameworks for energy markets and energy companies (including suppliers and network operators) are specified as an important criterion for the assessment of EE1 in Member States' energy policies. Furthermore, the monitoring of the implementation of EE1 could be included extending the criterion of monitoring. This monitoring of the implementation of EE1 is now recommended in the Commission's guidelines, and required in the new Article 3 of the proposed EED recast.

The comparability and straightforwardness of the composite indicators make it possible for the indicator to be easily applied as a checklist by the MS without complex intermediary steps. The interviews were used to review the applicability of the indicator in this context. During the interviews, our questions were easily understood and answered by all MS. And although the assessment of the MS regarding the implementation of the EE1 principle might include some degree of subjectivity, the overall results give a first overview on the dissemination and implementation of the EE1 principle in course of the NECP across the EU. To increase the robustness and the reliability of the results generated by the application of the EE1 indicator, it is recommended to expand number and the scope of interviewees. Furthermore, this should be supported by defining a list of interview partner with expert profiles, who hold similar positions and have similar influence on the development of the NECP in order to make the results more comparable.

The utilization of the indicator as an assessment tool is planned through its incorporation to the ODYSSEE-MURE database. This will enable policymakers and researchers to get an insight into the current state of the EE1 principle across the EU and within the MS. Additionally, it will support them in detecting existing weaknesses regarding national EE policymaking and point them towards areas, which still require more political attention and improvements to realize the full potential of EE. Regarding the application of the indicator as a guide in the operationalization of the EE1 principle, the 13 criteria illustrate the multiple aspects of the principle and can be utilized by the MS as a checklist to support them in their realization of the EE1 principle. For validity reasons, we recommend a thorough consultation of a broad range of stakeholders regarding the weighting factors in the future and adjusting the weighting scheme of the criteria accordingly to increase its overall quality and acceptance. While this would then make

it more difficult to identify trends and changes in the practices over time, this disadvantage could be addressed by adding one or two more levels for each criterion that will be defined to anticipate more advanced practices, or to use more differentiated levels compared to the current three levels. For instance for the assessment of the EE1 principle until 2030, we assigned less relevance and thus a lower weight to sufficiency. However, the consideration of sufficiency will become more important in policy plans, which extend until 2050. Therefore, in future application of the indicator and future research, this aspect should be taken into account.

Conclusions

The EE1 principle is a multifaceted concept, which requires the consideration of a range of aspects to make it fully operational. One aim of this paper is to shed a light on the multiple aspects and steps necessary to make the EE1 principle fully operational. The second aim is to create a tool, which facilitates the assessment of the operationalization of the EE1 principle across the EU. The 13 criteria of the indicator reflect those multiple steps and the scoring system allows its quantification. The result is a multidimensional indicator approach with the capacity to deliver information about the overall performance of countries and to highlight deficiency and areas, which still need to be incorporated by the MS.

Our indicator approach provides a step-by-step guideline, which supports the MS in making the EE1 principle operational. Policymakers can utilize our indicator early in the policymaking process to ensure that the various aspects of the principle are considered in every stage of the process. The compliance with the criteria can help them to identify the economic EE potentials and thus support the promotion of EE policies. Furthermore, the approach can be used to assess the current state of the EE1 principle across the EU and allows to compare the performances of the MS. The additional information on the single criteria makes it possible for countries to exchange knowledge and learn from the best performing countries in each category. While the indicators already deliver significant insights on the application of the EE1 principle, further improvements, e.g., in form of more elaborated data collection or review process consulting a broad range of stakeholders, can enhance the quality of the indicator.

The operationality of the indicator was demonstrated by its application to 14 MS to test the degree of compliance with the EE1 principle in the development of their NECP. While the results should be considered with caution due to the limited data use, the results provided a first impression. Based on the information collected for this pilot assessment, the majority of MS scored at least 1 in 40 to 50% of the criteria set in our indicator approach regarding the EE1 principle in their NECP. The main deficiencies lie in the failure to compare demand-side and supply-side options on equal terms with each other. As the Governance Regulation does not specifically requires it, only 21% compare both the costs and benefits, while in remaining MS, the decision-making is driven by cost-minimization or political influence. In addition, most countries neglect the wide range of MBs associated with EE improvements and apply higher discount rates for EE solutions. As a result, the benefits of EE investments are often undervalued, and the costs are overestimated, which in turn reduces the number of cost-efficient EE opportunities in impact assessments. While 90% of the MS provide measures to overcome financial and informational barrier, over 50% fail to include any provisions to reduce regulatory and non-technological risks related to EE investments. Furthermore, the review of historic preferences for supply-side resources, as well as the reversal of biased measures because of those historic trends, do not seem to present a concern to MS. In conclusion, it could be assessed that the MS have mainly understood and implemented the fundamental idea of the EE1 principle, but progress has still to be made regarding the more detailed aspects of the principle.

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Declarations

Conflict of interest The authors declare no competing interests.

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