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How does knowledge utilization influence climate policy innovation? Energy modelling and the legitimization of the 55% target in the European Union

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ABSTRACT

In order to accelerate the energy transition, policies have proven successful to reduce emissions, but more policy innovations are needed to reach carbon neutrality. Despite some understanding of the process of such innovations, the role of knowledge is not addressed in a systematic way. In particular, the role of energy models has not been investigated thoroughly. In this article, we examined the types of knowledge utilization and the ways in which they influence the development of policy innovation. We focused on energy modelling and conducted a case study of the European Union's (EU) 55% climate target for 2030, and analytically distinguish three uses of model outputs (rational, legitimizing and enlightening), for which we nuance who uses what knowledge to what effect. Based on a qualitative content analysis of 33 text documents and 12 semi-structured interviews with EU policy modelers and policymakers, the results indicate that energy models enable and constrain policy innovations. Model outputs were mainly utilized to legitimize the previously formulated 55% target, but also in rational and enlightening ways for the development of a policy mix to achieve this target. However, the absence of assessments of higher targets might have inhibited the adoption of a more ambitious policy. Based on these results we identify enabling and inhibiting factors for the use of energy models in policymaking. Beyond energy modelling, the study develops our understanding of how different uses of knowledge affect policy innovation and lays the foundation for future studies on the uses of different kinds of knowledge.

1. Introduction

There are many approaches to accelerate energy transitions [1], and policies have proven to reduce emissions significantly, for example through putting a price on fossil fuels, and pushing the development of new technologies [2]. However, the current policy mix is not yet sufficient to achieve the Paris Agreement, and new policies are needed [3]. The process of creating such policy innovations has been the subject of some research [4,5]. It defines policy innovation as novel and significant changes in the aims and instruments of a policy [4], as well as changes in problem perception, or policy process [6]. While some sources and patterns of policy innovation have been identified [5], the innovation processes of energy transitions have only been investigated to a limited extent [7]. Existing investigations remain limited to the multiple streams framework, policy transfer, or policy learning [8–10], but there is a plethora of theories of the policy process that could inform studies of policy innovation [11].

One prominent factor for policy change is knowledge [12,13]. It is involved in every policy process and can serve different purposes, including the structuring of policy problems, the forecasting of outcomes of policy options, as well as the monitoring and evaluation of policy performance [14]. For all of these purposes, different kinds of knowledge can be involved. On one hand, there is experiential, or local knowledge, which derives from trial-and-error learning related to a topic in a specific place [15]. On the other hand, there is expert-based knowledge, which is content that is created by established scientific, technical, and professional modes of inquiry [13]. Expert-based knowledge is often seen to have more impact on policymaking, due to popular perceptions that science is neutral and objective [13]. However, this knowledge is often not directly translated into policymaking [16,17], and instead it is used for political gains. Such diverging ways in which knowledge is used in policymaking have been documented by the literature on knowledge utilization [18].

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However, in the literature on policy innovation, the role of knowledge has only been covered as a side-aspect. Existing research has, for example, focused on evaluations as a form of knowledge and established that evaluations contribute in different ways in the different stages of development of a policy innovation [19]. Further, there has been research into policy innovation labs, which aim to generate knowledge about the effectiveness of policy prototypes [20]. Another line of research has shed attention on policy learning, which explores the processes of how policy actors acquire, circulate and interpret policy-relevant knowledge in order to create policy innovation [6]. The activities of policy entrepreneurs have been of special interest, as they combine knowledge, resources, and opportunities to promote policy innovations [4,21]. However, so far we know little about whether the way in which knowledge is utilized affects the extent of policy innovation. Potentially, it could have effects on the content and extent of policy innovation, its diffusion to other countries, and the outcomes of the final policy.

To address this lack of systematic understanding of the role of knowledge on policy innovation, we raise the following research question: *How does knowledge use affect the extent of policy innovation?* As a policy innovation, we select the EUs climate target for 2030, which was adopted in 2021 and set the goal of a 55% reduction of greenhouse gas (GHG) emissions in comparison to levels from 1990. It is innovative in the ambition of the target, and laid the foundation for the innovative instrument mix of the "Fit for 55" package, which makes it a key EU climate policy innovation. We focus on the outputs of computerized energy models, because they are often said to become more and more crucial for supporting the development of tailored policy interventions in the energy transition [22–24]. Computerized models are computer-based mathematical simplifications of reality that produce future-oriented knowledge. They are a form of expert-based knowledge that is often viewed as particularly objective and neutral, because of the complex calculations they perform. They are often part of impact assessments in many policy processes [25,26], but—similar to knowledge in general—their role for policy innovation has not been explored systematically in the literature on the energy transition.

2. Literature review

In this section, we synthesize different literatures to systematically analyze the relationships between the different ways in which knowledge is used, and their impact on policymaking. First, we draw from the literature on policy innovation to detail what policy innovations entail. Then, we borrow insights from the literature on policy learning on how learning from knowledge can lead to policy innovation. We complement this with the different ways in which knowledge can be used in policy making, which we distil from the literature on knowledge utilization. This allows us to study the role of knowledge as a crucial process in the creation of policy innovation. Finally, we introduce energy modelling as a form of knowledge, and review how it has been studied in the context of policymaking.

2.1. Policy innovation in the energy transition

There are two requirements for policies to count as innovations. First, they have to represent a novel change within a specific context, either through introducing new elements to a policy, or through the translation of policies from other jurisdictions [4]. Second, they have to induce a significant change from the status quo that goes beyond incremental change of minor details and elements of the policy. Policy innovation has been studied from the perspectives of policy invention, policy diffusion, and policy evaluation [4].

While policy innovation can be studied as an outcome with a focus on policy design, a focus on the process can allow to understand how policy innovations emerge [4]. Key policy innovations have been found to be a slow process that takes several minor innovations and travelling of ideas between jurisdictions until the innovation is complete and impactful [27]. In this process, policy entrepreneurs and other actors are important for promoting innovations [21,28,29], and they rely on windows of opportunity for a successful adoption [30]. The quality of the process can have influence over how effective the policy is after its adoption [31]. An important aspect of the process towards policy innovation is learning. For example, the Chinese government has managed to accelerate its energy transition by strategic collaborations to translate energy transition policies from Denmark to China [32].

2.2. Learning for policy innovation

When studying policy learning [33,34], scholars have established to differentiate between who learns, learns what, and to what effect [35]. As for who learns, there is a range of social and state actors that can potentially learn [35]. Learning can occur at different levels: the individual level, group level, organizational level, and also at a collective level of political systems [34,36]. In a narrow perspective, modelers, policy advisers, policymakers, and politicians can learn about policy problems and instruments with likely effects on policy development. Moreover, the media, industry, or civil society can also learn about policy, eventually leading to policy change [6].

What these actors learn about is another important component of policy learning. Bennet and Howlett [35] found that learning can be about the organizational features of state bureaucracy, about policy instruments and programs, or about beliefs and values. Another differentiation on what is learned is provided by Goyal and Howlett [6], who differentiate between learning about how policy issues and objectives are framed (problem learning), learning about policy instruments and their calibrations (policy instrument learning), and learning about the politics of the policy process (political learning). Overall, an extensive list of types of learning has evolved in recent years [34,37].

Lastly, learning can result in different effects [35]. It results in policy innovation, when it leads to a novel and significant change in either the problem perception, or the goals and targets of a policy (policy objectives), or the tools to achieve the targets (policy instruments), and lastly also the design and organization of the policy process [6,38]. In sum, the specification of who learns, learns what, and to what effect adds nuance in understanding policy learning from knowledge for policy innovation. However, the literature on policy learning rarely focused on how the creation and utilization of knowledge influence the extent of policy innovation.

2.3. Knowledge utilization for policy innovation

There is a long record of studies that focused on the use of knowledge in policymaking (e.g. [16,18,39,40]). On one hand, there are rationalist approaches, which strive for more objective evidence-orientation in policymaking. On the other hand, there are constructivist approaches, which highlight that evidence is a subjective interpretation, and acknowledge that in practice knowledge is often not correctly used. However, Newman [41] has argued that these perspectives in fact do not oppose, but rather complement each other. Many different uses of knowledge have been identified by Weiss [18], and a lot of uses have been developed in many contributions since, for example conceptual, symbolic, political, learning, rational, and instrumental [42–45]. However, they are often overlapping and interchangeable, se we stick to the uses of Weiss and select the three that are most commonly used—that is rational, legitimizing, and enlightening uses.

A rational use occurs when research is conducted to directly solve a policy problem and the decision for solving this problem then follows from the research findings [18]. This type of model use can be associated with a technocratic and rational approach to policy analysis that stands in contrast with other forms of policy analysis that focus more on political or deliberative aspects of public decision-making [46,47]. Knowledge can also be used in a legitimizing way when policymakers select information to advance their policy preferences. This selection is based on the constellation of interests around policy issues, or ideology and reflects a political use of expertise [18,43,46]. One motivation for this can be the depoliticizing effect of knowledge, which is often viewed as neutral and objective, and is therefore often used to resolve policy conflicts [48,49].

The situation in which policy actors expand their understanding of an issue and its solutions is described as enlightenment use [18], also often referred to as conceptual use, or learning use [13,45]. Compared to rational use, knowledge is not directly translated to policy but accumulates and may eventually lead to a new perception of policy problems and solutions, and thus indirectly to policy innovation. These three knowledge uses provide a useful lens for analyzing the diverse ways in which knowledge informs learning that leads to policy innovation. Yet, this relationship has rarely been investigated, both generally and in the context of knowledge from energy models.

2.4. Utilization of energy models in policymaking

There is a growing body of literature on the intersection of energy models and policymaking. It has investigated how modelers view this intersection [50,51] and mostly deals with the question of how modelling can be improved to be more usable or impactful in policymaking [52–54]. Despite improvements in energy modelling, uncertainties remain [55], and model development is still inflicted with politics [48,56,57]. For example, there is a lack of diversity in the backgrounds of models and modelers [58], and bias in the selection of scenarios [59]. However, most of this research focused on the generation of models, and not how energy models are used in policymaking from a user-oriented perspective. The few studies who did note a widespread use of energy models at the national level, and only few applications at the local level [60,61]. The use of energy models in low- and middle income countries is mixed and ranges from no use, to minimal use, and fundamental use [62].

The first systematic analysis of how energy models influenced policymaking was reported by Süsser et al. [26], who found that energy models inform and support decision making at different stages of the policy process, for example to explore energy futures, pathways, and scenarios. They recognize that models can be used politically to generate results that support existing policy preferences, but they do not investigate different uses of modelling outputs by different actors, and their influence on policy innovation in a systematic way. Therefore, this study merges the insights from the literatures on policy innovation, policy learning, and knowledge utilization into an analytical approach to address the gaps in the literature (Table 1). Next to a differentiation of the different modes in which knowledge is used, we add the questions from the literature on policy learning to nuance the knowledge uses further. In this context, “who learns, learns what, and to what effect” is translated into “who uses knowledge”, “what knowledge”, and “what is the effect on policy innovation”.

Table 1
Conceptual synthesis of knowledge use for policy innovation.

Analytical questions	Subset of answers
Who uses knowledge?	Policymakers; Policy advisors; Modelers; Politicians; Media; Industry; Civil society
What knowledge?	Knowledge about: Policy problems; Policy instruments and programs; Policy values and beliefs; Political strategies
In which mode is knowledge used?	Rational use; Legitimizing use; Enlightenment use
What is the effect on policy innovation?	Change of problem framing and goal setting; Instrument selection; Process design and organization

3. Methodology

3.1. Case selection and background

We adopt a case study research approach [63] to create an extensive in-depth examination of an exemplifying case of energy modelling within a policy innovation. The policymaking process of the 55% target started in 2019 and finished on June 30th, 2021, with its adoption in the context of the European Climate Law (Regulation (EU) 2021/1119). It marked a significant change from the previous target of 40% reduction that was novel in its magnitude in the context of the EU [64,65]. It further laid the foundation for the adoption of numerous other policies in the subsequent “Fit-for-55” package [28,66,67], and for transpositions of these policies in the Member States. This makes it a major policy innovation in EU climate policy in the past few years. Moreover, the EU is often seen as a frontrunner in the utilization of models, and disposes of considerable modelling capacity [68,69].

In this policymaking process, energy models were deployed in the Commission's impact assessment to estimate the economic, social and environmental effects of the changes in policy instruments that were deemed necessary for reaching the potential climate targets [70]. The assessment included on one hand techno-economic models such as PRIMES [71], which simulate the introduction of a policy into the energy market in order to simulate the feasibility of technological changes in the energy system. On the other hand, it included macroeconomic models such as JRC-GEM-E3 to simulate the corresponding economic impacts on society, for example on economic growth, competitiveness, and employment [72]. We focus on macroeconomic modelling, because research has indicated that industry-related actors often refer to macroeconomic risks of renewable energy systems when they veto proposed climate policies [73,74].

The macroeconomic analysis of the Commission included three macroeconomic models: One of them is JRC-GEM-E3, which is a computable general equilibrium model that is based on neoclassical economics [75], and operated by the Joint Research Centre (JRC) at the European Commission. This model was for a long time dominant in assessing economic impacts [76]. Another model that was used is E3ME, which is an econometric model based on post-Keynesian economics, which is operated by Cambridge Econometrics and does not assume equilibrium [76,77]. Yet another type of model is represented by *E-QUEST*, which is a dynamic stochastic general equilibrium model that is built on New-Keynesian assumptions [78]. It is operated by the Directorate-General for Economic and Financial Affairs (DG ECFIN) in the European Commission and was used for the first time for climate policy. The impact assessment by the Commission was also used to inform decision-making in the European Parliament and the Council of the European Union (henceforth, ‘the Council’) (Section 5.2).

3.2. Data collection

We use 33 text documents and 12 semi-structured interviews to explore in what ways knowledge from models has been used. In September 2024, we gathered policy documents from the websites of the European Commission, Parliament and the (European) Council. We included legislative acts, impact assessment reports, stakeholder consultation reports, and policy proposals that pertain to the Climate Law or the 2030 Climate Targets. We complemented these documents with news articles from the websites of Politico and Euractiv, where we browsed the timelines of the energy and climate sections for news articles that covered the target process in the period between 2018 and 2021 (see Supplementary material, ANNEX A for a list of all sources included). We read this material and summarized the main messages on the events of the policy process, modelling results, and the policy outcome of the 2030 target process.

Next, we conducted a total of 12 semi-structured interviews between September and October 2024. Seven interviews were conducted with economic modelers that were involved in the creation of the impact assessment (referenced as "modeler 1–7" in the Results section). In addition, five policymakers and analysts were interviewed that were involved in the policy formulation and decision-making of the EU's 2030 Climate Targets (referenced as "policymaker 1–5" in the Results section) (see Supplementary material, ANNEX C). The interviews focused on the decision-making process on the 55% target, and the impact and role of modelling on the final policy design (see Supplementary material, ANNEX B). The interviews lasted 45–75 min each, were held online as a Microsoft Teams meeting, were recorded, and thereafter transcribed manually.

3.3. Data analysis

We conducted a qualitative content analysis on the collected text documents and interview transcripts. The first author coded quotations of these materials utilizing the software Atlas.ti 9.0.18 for Windows [79]. Quotations were coded abductively, starting from general codes on model development, modelling results, model use, policymaker model interaction, policy process, and policy impact [80]. From this, the case was reconstructed, including the policy process with a special emphasis on the impact assessment, as well as the different instances where models contributed to policy changes. This revealed that concepts of knowledge utilization and policy learning were central to our results, so we synthesized those concepts and adapted our codes for the type of knowledge use (rational, legitimizing, enlightenment), the model output, the user of the model output, and the impact on policy (see Supplementary material, ANNEX D). Throughout this process, the coding scheme was double checked by all authors.

We assessed the type of knowledge use in policymaking as follows: A rational use is present when insights from macroeconomic modelling are directly and intendedly used to modify policy design. An enlightening use prevails if the modelling evidence contributes to learning among policy actors, but not necessarily changes their beliefs, or has impact on policy design right away. Lastly, a legitimizing use is at hand when knowledge is used to support preexisting policy preferences. The outcomes of these uses qualified as policy innovation, whenever they represented novel and significant changes in the policy objectives, or instruments.

4. Results

We identified three model outputs and five instances of their use in the policy process. These uses ranged from legitimizing to enlightening and rational, and had different impact on policy innovation (Section 4.2). A first question in which model uses occurred was about which target to select as a new climate target for 2030 (Section 4.2.1). A second question for which models were used relates to the design of the instrument mix for achieving the 55% target (Section 4.2.2). The third question for which models were used was about the economic implications for different households (Section 4.2.3). In summary, modelling results were used differently in various venues, for several questions, and resulted in several policy innovations. But first, it is important to understand the policy process in which these uses occurred (Section 4.1).

4.1. Policy process of the 55% target

4.1.1. Proposal on a new climate target for 2030

In 2018 and 2019, climate action was salient on political agendas in Europe following extreme weather events, social movements, and scientific reports (Fig. 1) (policymaker 4; [81]). As a response to these external pressures, the Commission published the strategy "a clean planet for all" in November 2018, where it assessed the feasibility of becoming climate-neutral by 2050 [71]. In this strategy it did not mention new climate targets for 2030 and deemed the previous 40% target from 2014 sufficient to comply with the Paris Agreement [82–84]. In contrast, the European Parliament suggested a new climate target for 2030 by adopting a new 55% target in its resolution on the 2018 UN Climate Change Conference in Katowice, Poland (COP 24) [85].

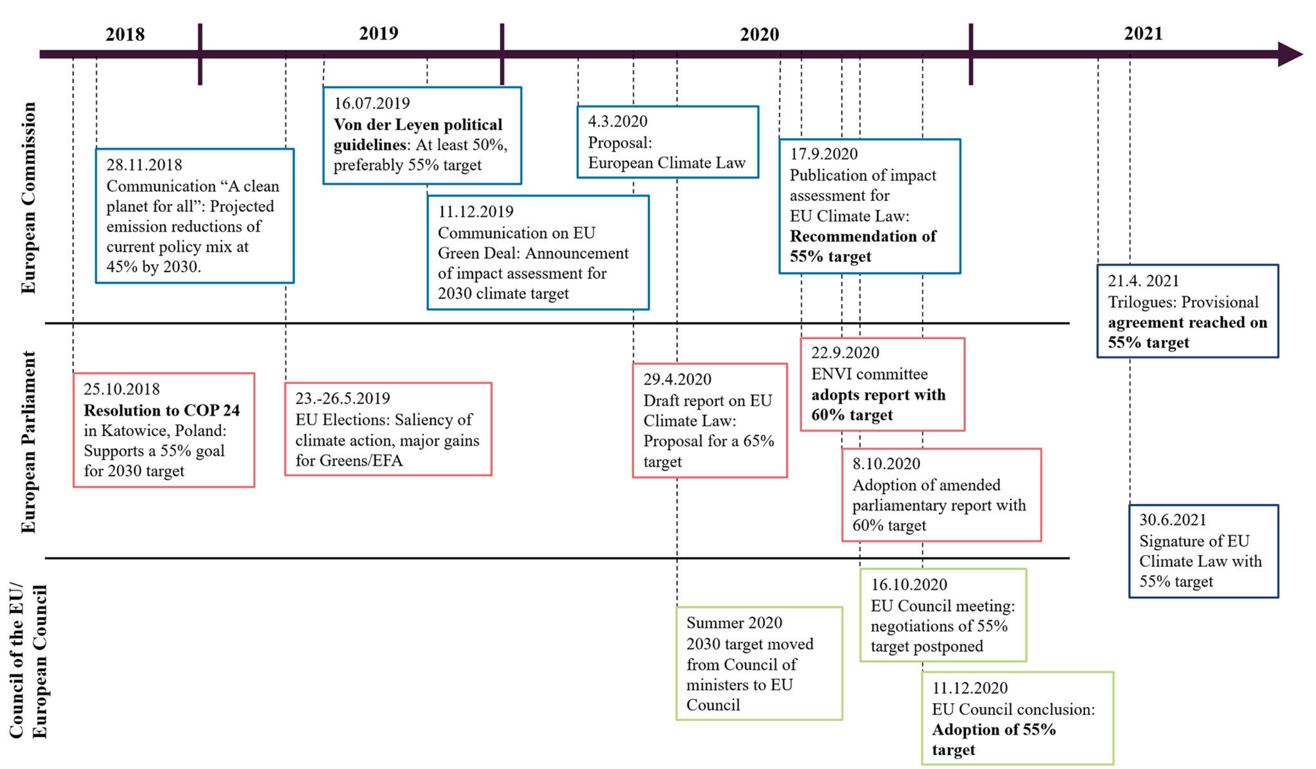

Fig. 1. Timeline of the policymaking process of the 55% target.

In the run up to the EU elections in June 2019, even conservative parties promised to deliver on climate action in their agendas, but the elections still resulted in large gains for the Greens-European Free Alliance (Greens/EFA). Ursula von der Leyen was elected new President of the European Commission, but only with a scant majority of nine votes by the Parliament [86]. To allow for broader alliances including also the Greens/EFA in the Parliament, von der Leyen prioritized the Green Deal (policymaker 3 and 4; [66,87]), and advertised new climate targets for 2030 [88,p.6]:

"I want to reduce emissions by at least 50% by 2030. [...] I commit myself to putting forward a comprehensive plan to increase the European Union's target for 2030 towards 55% in a responsible way. This plan will be based on social, economic and environmental impact assessments that ensure a level playing field and stimulate innovation, competitiveness and jobs."

This political choice of a 50% and a 55% target framed the development of the subsequent policy formulation. The targets were included in the Green Deal communication [89], and the proposal for a European Climate Law [90]. Following institutional procedures, the Commission then conducted an impact assessment under the lead of the Directorate-General for Climate Action (DG CLIMA) [78], and recommended the adoption of a 55% target [70,91]. Thus, the external pressures, and institutional procedures enabled the use of energy modelling for the 55% target.

4.1.2. Adoption of the 55% target

In the Parliament, the Committee on the Environment, Public Health and Food Safety (ENVI) appointed Jytte Guteland from the Socialists and Democrats (S&D) as a rapporteur for the parliamentary draft report, in which Guteland pledged for a 65% target [92]. This target was amended to a 60% target in ENVI [93] and finally became adopted by the Parliament (policymaker 3 and 4; [94,95]). The Parliament was lacking resources to conduct a macroeconomic analysis of the 60% target and asked the Commission to assess it, but the Commission declined, because it questioned the political feasibility of a 60% target among MS (policymaker 4; [96,97]).

In the Council, some MS were pushing for the 55% target, and some MS were concerned about the economic impact of a higher target. The acceptance of the target was further complicated by budget cuts in the Just Transition Fund [98,99]. Eastern European environmental ministers wanted to await the Commission's impact assessment [98], so it was only placed on the agenda of the European Council in October 2020. There, remaining issues should be solved by heads of states or governments (policymaker 3; [100–102]), and Poland and Hungary used these negotiations for bargaining advantages related to ongoing issues with the rule of law and the EU's Multiannual Financial Framework.

An agreement on the 55% target was only reached in the following meeting of the European Council in December 2020 [87,103–105]. This unanimous decision marked a decisive point in the adoption of the 55% target, because it represents a compromise at the highest political level (policymaker 3; [106,107]). Later in the interinstitutional negotiations (i.e. 'Trilogues'), Parliament representatives were not able to raise the target to 60%, also because it lacked backing from an economic assessment [87]. Nevertheless, the Parliament was able to include their proposals for establishing a climate target for 2040, and the inclusion of additional carbon removals so that GHG emission reductions would add up to de facto 57% (policymaker 4; [107]). Finally, the 55% reduction target was signed on June 30th, 2021, as part of the European Climate Law (Regulation (EU) 2021/1119) [108].

4.2. Model usages and effects on policy innovation

4.2.1. Selecting the 55% target

The central question which macroeconomic models were applied for was on the impact of a new climate target for 2030. In its impact assessment, the Commission evaluated a 50% and a 55% target [78]. There was no preliminary analysis to inform the choice of these targets (policymaker 5), so they likely result from the political guidelines of Ursula von der Leyen, and thus political considerations of which targets would be feasible to be adopted by Parliament and Council. These targets were then assessed by all three macroeconomic models by calculating impacts economic indicators, such as gross domestic product (GDP), competitiveness, employment, and investment [78]. As a result it stated that both targets have a limited macroeconomic impact (policymaker 5; modeler 4; [78]), and thus recommended the 55% target.

Therefore, the impact assessment had a legitimizing function for the previously articulated preference of the Commission for the 55% target (modeler 4). The analysis lent authority and legitimization to the 55% target and allowed to motivate the policy changes of the subsequent "Fit for 55" package (policymaker 3 and 5; modeler 4). Despite this legitimizing use, interviewees emphasized that the modelling exercise was conducted in an open-ended manner without manipulation or suppression of results (modeler 2, 3, and 4) and the "impact assessment was not just to rubber stamp the proposal" (policymaker 5). Nevertheless, the politicization of climate action and the time pressure in the policy process catalyzed the narrow selection of a 50% and 55% target in the assessment, which inhibited a more exploratory approach to assess the targets.

By the time the Commission published the impact assessment, the Parliament had already adopted a 60% target, following deliberations in the ENVI committee [70,93]. The Parliament lacked resources to conduct its own modelling and asked the Commission to assess the 60% target, but its request was rejected. Nevertheless, the Parliament still used the impact assessment in a legitimizing way to conclude that even higher targets than 55% may have a low economic impact (policymaker 4). However, the absence of modelling on the 60% target weakened the bargaining position of the Parliament in the Trilogues (policymaker 4), which highlights the power of the impact assessment to legitimize policy preferences. In sum, the more democratic deliberative spaces in the committees of the Parliament enabled more ambitious targets and generally a willingness to engage with analysis from modelling, but the lack of capacity to conduct own assessments, and dependency on the Commission inhibited a more learning-oriented use of macroeconomic modelling.

In the Council, some MS utilized the insights from macroeconomic modelling to legitimize and push for the 55% target. Other MS pointed to the lack of granularity in the models, as they did not provide insights into national and regional economic impacts, which they feared would be significant for some MS (policymaker 3 and 5).

"[...] impact assessments by the Commission of course look more overall for what this means for the Union, sometimes also at the sectoral level, but it doesn't always provide the really granular data for at Member States level to really work out what this means exactly for you as Member States, so that would be a process that you do together with your colleagues in the capital"

(policymaker 3)

However, not all MS have the policy capacity to conduct such analysis on a national level and from our material, there is no indication of formal national impact assessments before the decision of the European Council in December 2020. Hence, MS likely relied on internal ministry briefings, which are not publicly accessible, so it remains unclear whether and to what extent national analyses of the macroeconomic impact informed the positions of the MS, and in which way they were utilized (policymaker 3 and 5). Model use in the Council was enabled by deliberative spaces such as the preparatory working groups, but the lack of policy capacity of the MS in the Council to model impacts on national levels, as well as political bargaining in the European Council inhibited more evidence-orientation.

In sum, the macroeconomic modelling result of the limited impact of a 55% target was used in a legitimizing way in the European organizations to adopt the innovative 55% target. As a consequence of the new target, subsequent innovations in the policy instruments were needed and later adopted in the "Fit for 55" package. This shows that macroeconomic modelling can support policy innovations through informing the selection of innovative policy targets. They do so by testing the feasibility of, and providing argumentative authority to the previously articulated 55% target, which was suggested as an outcome of political decision-making.

4.2.2. Instrument mix for achieving the 55% target

The second aim of the macroeconomic analysis was to explore the impact of different policy mixes to achieve the 55% target:

> *"We knew that we would keep the architecture more or less as it is, [...] but we need to raise ambition, and raising ambition could have gone through different instruments, again, more towards carbon pricing and more towards regulations, so we looked at these broad scenarios, without making any specific proposal in the 2030 impact assessment"*
>
> (policymaker 5)

For this, the effects of four different policy mix scenarios were included in the analysis by JRC-GEM-E3, ranging from regulatory to pricing mechanisms. One scenario was the baseline of the existing policy mix, another scenario focused on regulation-based instruments (REG), a third scenario focused on carbon pricing (CPRICE) and the last scenario mixed pricing and regulation (MIX) (policymaker 5; modeler 4; [78]). The MIX scenario was found to have the least negative impact on the economic impact indicators, and a mix of regulatory and pricing mechanisms was chosen as a design principle for the "Fit for 55" package (policymaker 5).

The use of these model results is less clear and could range from rational to legitimizing. On one hand it could be rational as there was a knowledge gap and the macroeconomic modelling provided an indication for the choice of additional instruments (policymaker 5). On the other hand, it could have legitimized a preference for a mix of instruments that is indicated in previous policy documents such as the Green Deal. Here, the Commission states its intent to "make consistent use of all policy levers: regulation and standardization, investment and innovation" [89,p.4]. Similar preferences can be seen in the buildings domain. In case of a rational use, macroeconomic modelling was enabled by the existence of a knowledge gap, and the secondary, depoliticized character of this question. In case of the legitimizing use, a more rational use was inhibited by the authority of the Commission in conducting the impact assessment.

The result of the preference for a mix of pricing and regulatory instruments was that the subsequent "Fit for 55" package introduced both pricing and regulatory instruments in several sectors as policy innovations. In the building sector, this involved the Energy Performance of Buildings Directive (EPBD) (Directive (EU) 2024/1275) as a regulatory instrument, and the ETS2 (Directive (EU) 2023/959) as a pricing mechanism. In the electricity sector, this included the revision of the Renewable Energy Directive (RED) (Directive (EU) 2023/2413) (regulatory) alongside the tightening of the ETS (Directive (EU) 2023/959) (pricing). In the transport sector, the CO_2 emission performance standards for cars and vans (Regulation (EU) 2023/851) were revised (regulatory), and the ETS 2 for buildings, road transport and additional sectors (Directive (EU) 2023/959) was formulated (pricing). Thus, macroeconomic models supported the selection of these innovative instruments through clarifying impacts, and legitimizing different instrument choices.

4.2.3. Compensating for distributional impacts of the 55% target

A third part of the impact assessment was the analysis on the distributional impacts of the target on households (modeler 4). For this, the trends for consumption from the JRC-GEM-E3 model were coupled in a novel way with household level data from the household budget survey (HBS) and fuel price changes [78]:

> *"We were looking at distributional implications [...], taking the price changes that we were getting out of our economic model for different consumption categories, and we were applying those to those 200.000 households and that would then tell us, okay well the high income households they are hit but not as much, whereas the low income households they spent more of their income on energy, so they would be hit predominantly stronger[...]. So that is then something I mean that needs to be taken into account in policy design."*
>
> (modeler 4)

These distributional impacts were particularly pronounced in the CPRICE scenario [109]. Moreover, the Commission explored how revenues generated from carbon pricing could be redistributed, for example through lump sum transfers, or tax recycling (modeler 4; [78]). These insights catalyzed a learning process about a compensation mechanism, for which additional, more detailed analysis was conducted in the later impact assessments of the "Fit for 55" package. This is why the analysis of the distributional implications represents an enlightening use of macroeconomic modelling.

Following the model results, eventually, the policy innovation of the Social Climate Fund[1] was adopted (SCF) (Regulation (EU) 2023/955) (modeler 4; [70]). It is worth to note that this was not a result of the impact assessment alone. Previous academic and policy debates had already acknowledged that higher CO_2 prices would require compensation for vulnerable groups. There was also societal pressure to address distributional implications from movements such as the 'Gilets jaunes',[2] and the Directorate-General for Employment, Social Affairs and Inclusion (DG EMPL) was getting more active in the climate policy domain [111] (modeler 4). Nevertheless, the macroeconomic analysis in the impact assessment marks the first instance where these have been modelled in a specific policy context (modeler 4, [78]).

Therefore, this example showcases that model results can facilitate innovative problem perceptions and initiate a learning process that leads to the development of a policy innovation. Finally, the model use may have been enabled by the knowledge gap, motivated by external pressures, and previous academic debates. In addition, the secondary character of the issue has contributed to the enlightening use of macroeconomic modelling for the distributional implications. An overview of all uses and innovations that we identified can be found in Table 2.

5. Discussion and conclusion

The main aim of this study was to develop our understanding of the relationship between knowledge use and policy innovation. We set out with the following question: How does knowledge use affect the extent of policy innovation? Results show that macroeconomic modelling both supported and constrained the emergence of policy innovation. The models were predominantly utilized to legitimize the previously articulated preference of the Commission for a 55% GHG emission reduction target. While they enabled the adoption of the ambitious target, they may have also constrained more ambitious targets. Nevertheless, the macroeconomic model results were also used in rational and enlightening ways for secondary questions such as the selection of policy instruments for achieving the target and the distributional effects of the 55% target.

Our case further illustrates that the type of knowledge use resulted from a combination of factors. The first factor relates to the nature of the

[1] The SCF aims at mitigating the negative effects of climate policies on the most vulnerable households and businesses through direct income support and funding for investments. It can be considered a policy innovation, because of its compensatory and redistributive nature that did not exist before at EU level [110].

[2] The Gilets Jaunes (Yellow Vests) movement emerged in France in November 2018 highlighting tensions between environmental goals and social equity, particularly in the context of economic inequality ([111]).

Table 2
Overview of identified uses of macroeconomic modelling.

Section	Policy stage	Model output (+ utilized model)	User of model output	Type of use of model output	Impact on policy innovation	Enabling conditions	Inhibiting conditions	References
4.2.1	Agenda Setting	The 50%/55% targets have limited economic impact. (JRC-GEM-E3; E3M-E; E-QUEST)	EU Commission (DG CLIMA)	Legitimizing previous preference for a 55% target	Adoption of 55% target	Institutional procedures, external pressures	Politicization, time pressure	Policymaker 3 and 5, [78,88]
4.2.1	Policy Adoption	The 50%/55% targets have limited economic impact. (JRC-GEM-E3; E3M-E; E-QUEST)	EU Parliament (Rapporteur, ENVI committee, Members of European Parliament)	Legitimizing prior preference for 60% target by highlighting limited impact of 55% target on GDP	No effect	Deliberative spaces	Lack of policy capacity, refusal of the Commission to assess a 60% target	Policymaker 4, [78,93]
4.2.1	Policy Adoption	The 50%/55% targets have limited economic impact. (JRC-GEM-E3; E3M-E; E-QUEST)	Council of the EU/EU Council (Working Party on the Environment; Committee of Permanent Representatives (COREPER); Environmental Council; German Council presidency; Hungary, Poland)	Legitimizing prior preference of some MS for a 55% target	Adoption of 55% target	Deliberative spaces	Political bargaining, policy capacity, granularity of analysis	Policymaker 3 and 5, [100,103,106]
4.2.2	Agenda Setting	A mix of regulation and pricing instruments has least economic impact (JRC-GEM-E3)	EU Commission (DG CLIMA)	Rational/ Legitimizing selection of (previously articulated) mix of instruments	Implementation of pricing and regulation instruments in the “Fit for 55” package	Lack of politicization, knowledge gap	Authority of Commission	Policymaker 5, [112]
4.2.3	Agenda Setting	Proportionally high burden on low incomes makes Social Climate Fund necessary (JRC-GEM-E3)	EU Commission (DG CLIMA)	Enlightening the need for a mechanism to compensate vulnerable households	Adoption of the Social Climate Fund after additional analysis	Academic debates, external pressure, lack of politicization, knowledge gap		Modeler 4, [78,109]

Note. Explanation of abbreviations: JRC-GEM-E3: Joint Research Center - General Equilibrium Model - Economy, Energy, Environment; E3M-E: Energy - Environment - Economy Model for Europe; E-QUEST: Energy-extended Quarterly European Simulation Tool; DG CLIMA: Directorate-General for Climate Action; ENVI: European Parliament Committee on the Environment, Public Health and Food Safety.

modelling tools— that is the dynamics that the model represents and the granularity of the analysis. Examples for these are the extension of JRC-GEM-E3 to assess impacts on the household level, or the lack of analysis of the impacts on MS level. A second factor is the content of the model, which is shaped by assumptions and the selection of scenarios in its development. For example, the decision to assess only a 50% and 55% target might have inhibited the adoption of a 60% target. Third, users are crucial, depending on their capacity to conduct, or understand, the technical knowledge involved. Lastly, and most importantly, overarching forces that shape the space of knowledge exchange may influence the type of knowledge use. This can be seen in political dynamics, for example in light of the European Elections 2019, or characteristics of the policy venues, such as the deliberative spaces in Parliament and Council.

5.1. Utilization of energy modelling for policy innovation

This paper contributes to the literature on energy modelling by clarifying how its use enables, but also limits policy innovation, and raises implications for modelers and energy researchers. Most importantly, the economic analysis legitimized the adoption of the relatively ambitious 55% target and this enabled subsequent policy innovations in the “Fit for 55” package. On top of that, energy modelling also informed the selection of policy instruments in that package, following a recommendation of a mix of pricing and regulatory instruments. Moreover, the analysis of distributional implications informed the design of a subsequent policy innovation in the case of the SCF. These examples show that evidence from energy modelling can play a vital role in creating, informing, and legitimizing policy innovation, adding a new perspective to our understanding of sources and patterns of policy innovations [5,6]. These findings suggest that policy makers and entrepreneurs can support innovative policy options through the use of energy models in various ways.

However, the use of energy models can also inhibit policy innovations. The scope of the macroeconomic analysis was defined narrowly by assessing only a 50% and a 55% target. This way it was difficult to argue for a 60% target, because its macroeconomic impact was not clarified, even though a 60% target may as well not have had significant economic impacts. On top of that, the macroeconomic models lacked insights on national and regional levels, and some MS used this gap to argue against higher targets, because they are critical of higher climate targets due to concerns of economic impacts (see also [113,114]). This then also allowed some MS to use the negotiations on the climate target as a bargaining chip on other issues in the European Council. In contrast, if the economic impacts on regional levels would have been assessed, it could have clarified the economic impacts and enabled a constructive debate about how to address and compensate for them in pursuit of higher targets. Therefore, the focus on assessing a limited selection of targets, and the lack of (sub-)national analyses might have contributed to the selection of a less ambitious target than what could have been possible, and the delay of agreement on the 55% target in the European Council.

This also underlines the crucial role of energy models for power dynamics in the policy process [56]. Since the Parliament and the Council lacked the capacity to conduct analysis on the 60% target, energy modelling lend argumentative authority to the Commission and allowed it to legitimize their preferred target of 55%. To prevent such unbalanced power dynamics, and facilitate a more democratic decision-making process, it is important that all policy actors can participate in the generation of policy-relevant knowledge in order to enable support for policy innovation. This could be achieved through a more participatory modelling process in the Commission that recognizes various positions of diverse policy actors (e.g. the Parliament, MS, industry, citizen assemblies or non-governmental organizations) and embraces an array of possible futures [115–117].

Moreover, this study adds to previous research on the use of energy modelling by Süsser et al. [26] that energy models can be utilized in legitimizing, rational, and enlightening ways. Previous work already recognized that models do not make decisions, but rather support decision-making, and sometimes even only legitimize existing policy preferences [26,118]. In contrast, our analysis provided a systematic assessment of these uses and uncovered a prevalence of legitimizing uses of the macroeconomic models for setting the 55% target in the Commission, Parliament, and Council. Thus, legitimizing uses might not occur only sometimes, but are more wide-spread in the utilization of modelling results.[3] This highlights the need for reflexive modelling approaches [56].

Our analysis further uncovered how these uses are enabled and inhibited by certain factors and add to the existing list of factors by Süsser et al. [26] that can inform frameworks of future studies. Most striking seems that for issues that are more politicized (i.e. selection of the target), legitimizing uses of energy modelling might be more prevalent, and for issues that are less politicized (instrument mix of the “Fit for 55” package), enlightening or rational uses are more likely. Another possible explanation for the presence of legitimizing uses might be that they touched on core policy beliefs [119], because setting a climate target is directly linked to whether there should be ambitious climate action or not. In contrast, issues that touch upon secondary policy beliefs might be more receptive for enlightening or rational uses. In our case this is true for the choice of a mix of pricing and regulatory instruments to implement the target, and for the introduction of the SCF to address social impacts, which represent more secondary policy beliefs [119]. These results suggest that modelers and policy analysts working with energy models need to consider the variety of factors that may influence the utilization models in the policy process.

5.2. Policy innovation through learning based on different uses of knowledge

The findings of this study do not only provide insights into role of modelling for policy innovation in the energy transition, but can also be extended to the role of knowledge for policy innovation in general. Our analysis marks the first comprehensive research on how types of knowledge use link to policy innovation, and therefore also contributes to the literature on policy innovation and knowledge utilization. For example, our results show that rational and enlightening uses of knowledge have helped exploring innovative policy options. Likewise, legitimizing uses of knowledge have legitimized the 55% target, and thus enabled subsequent policy innovation in the “Fit for 55” package. However, they have also likely inhibited the selection of a more radical, and hence more innovative climate target. Thus, legitimizing uses may have a mixed effect on policy innovation, and in case of legitimizing uses innovativeness might be limited by political feasibility rather than technical feasibility. With these results, our framework specifically challenges the common notion that new knowledge automatically creates policy innovation through learning, and instead provides nuances of different possible uses of knowledge. It does so by developing previous insights on political uses of knowledge for policy innovation [19] into a systematic approach that differentiates rational, enlightening and legitimizing uses (see Fig. 2).

The results of this study also contribute to the study of knowledge utilization [18] by nuancing what actors utilize knowledge, what knowledge is used, and what are the outcomes of this use on policy innovation. This allows insights into the different approaches in knowledge use of various actors. While the Commission used the impact assessment to legitimize its preferred 55% target, the Parliament concluded that higher targets may also not result in significant economic impact. Then again the Council was split between MS using the impact assessment to legitimize the 55% target, and MS raising concerns about the feasibility of this target by pointing towards gaps in the scope of the analysis. Similarly, our results establish that there are several knowledge outputs that may be used in the same process, and they can have impact on different elements of the policy innovation. For example, these are knowledge outputs on the impact of the target, or the instrument mix for implementing the target. These nuances of knowledge use, which derive from our conceptual synthesis allows researchers to recognize the complexity of knowledge uses in the creation of policy innovation. Lastly, this study also contributes to the literature on policy learning by opening up perspectives for a systematic study of the different motivations for learning (i.e. rational, legitimizing, tactical, symbolic), beyond anecdotal recognition that learning can follow political motivations to legitimize predefined objectives [36,120].

5.3. Limitations and future work

While our case study represents a robust examination of knowledge utilization in EU policymaking, some limitations must be borne in mind while interpreting and generalizing our findings. Limited access to interviewees in the (European) Council constrained our assessment of knowledge utilization. Often, crucial information is confidential, such as the ministry briefings, which would have been helpful in determining the extent to which MS have utilized national analyses. Further, the patterns of utilization of energy models might differ in other contexts, such as national/regional levels, in authoritarian regimes, or non-Western states.

Therefore, more research is needed in different contexts, cases, jurisdictions, or regions in order to arrive at a better understanding of the use of energy models, enabling and inhibiting factors, and their roles in policy innovation. For these other cases, it could be interesting to look at less politicized policy innovations in order to see whether legitimizing uses of modelling are still prevailing in those contexts. Another avenue would be to study the use of more innovative, participatory, and open models and see how it differs in the process of, and impact on policy innovation. Lastly, it would be of merit to track how models and policy innovations develop over a longer period of time, for example by applying policy feedback theory [121]. This could add to our understanding of the lock-in effect of models, and how more innovative models could enter such policy processes.

Moreover, future research could study knowledge use of other forms of knowledge besides modelling (see [15]), and clarify their relation to policy innovation. We would expect other forms of technical knowledge and local knowledge to have less impact on policy innovation, because their authority in creating legitimation is often perceived lower than models, which are commonly seen as more sophisticated analyses. In contrast, we expect policymakers and analysts to rely more on experiential knowledge when formulating policies. Finally, all of this future research could benefit from a review of the different terms of knowledge use that are applied in existing research, for instance tactical use, symbolic use, legitimizing use. They currently overlap partly, but they also refer to different nuances in knowledge use. A review could bring them together, compare them, define them and outline boundaries between them.

[3] It is worth to note that legitimizing uses do not necessarily involve a problematic manipulation of evidence, but legitimation can be rather seen as “a nuanced concept that relates to the extent to which [evidence from models] has become an object of political negotiation, or been used to support a political position” [44].

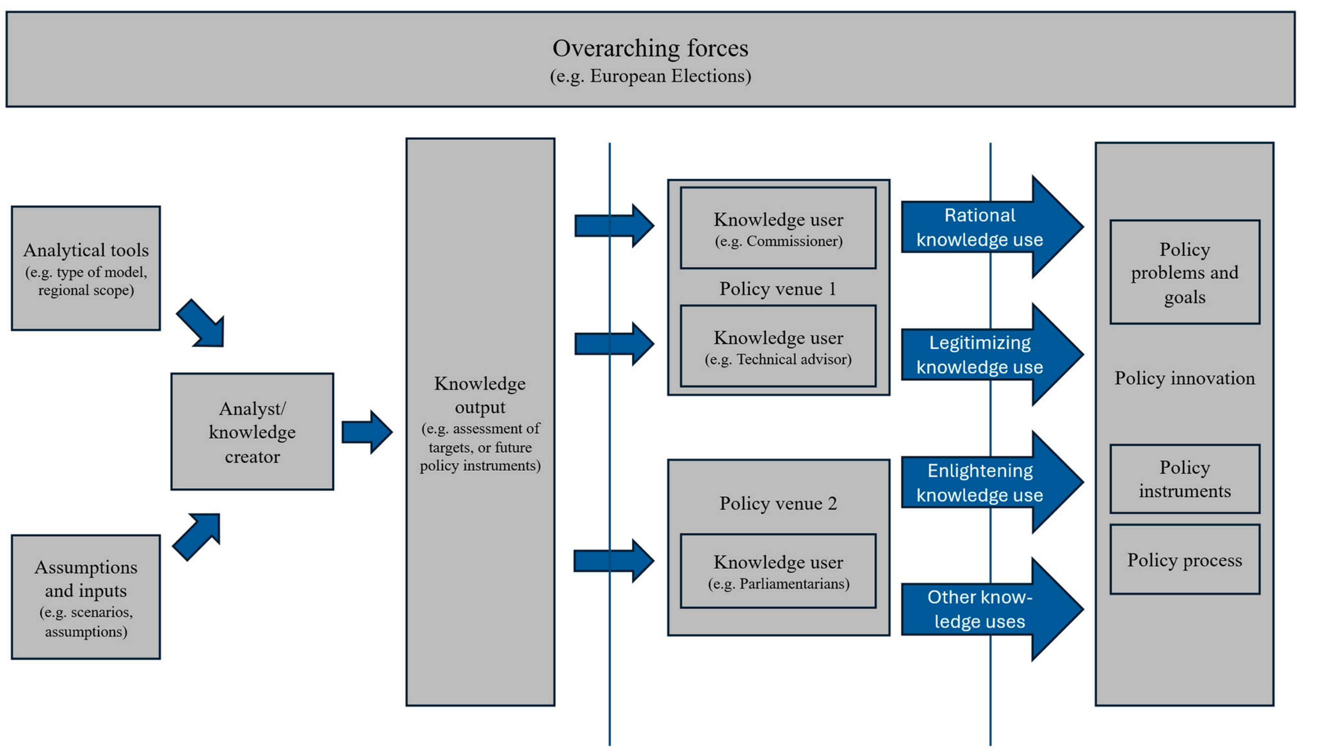

Fig. 2. Framework for studying the role of knowledge uses for policy innovation.

Despite these limitations and need for future research, our case study is an important illustration of how energy models contribute to and constrain policy innovation, and draws lessons for modelers and energy researchers. Moreover, it informs our understanding of policy innovation processes by highlighting how different knowledge uses affect policy innovation, and what are enabling and inhibiting factors for these uses. Further, the synthesis of the concepts of knowledge utilization and policy learning contributes to a more nuanced understanding of the use of knowledge in policymaking by distinguishing who uses knowledge, what knowledge, and to what effect. Lastly, it also contributes to the literature on policy learning by establishing that there are different motivations for learning.

CRediT authorship contribution statement

Stephan Huber: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Nihit Goyal:** Writing – review & editing, Supervision, Project administration, Conceptualization. **Thomas Hoppe:** Writing – review & editing, Supervision. **Tamara Metze:** Writing – review & editing, Supervision.

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Declaration of competing interest

“We have nothing to declare.”

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2026.104947.

Data availability

The data that has been used is confidential.

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