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Energy citizenship for inclusive decarbonization: A transdisciplinary framework for creating transformation knowledge

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ABSTRACT

Achieving the European Union's vision of climate neutrality by 2050 dictates the need to transform the role that citizens can play in decarbonizing the energy system. Yet, "which citizens to involve in this process," "when to involve them," and "how to do so fairly and effectively," are questions that still remain unclear to both experts and policymakers. Energy citizenship has been discussed as a concept that has the potential to galvanize the public for the energy transition. This potential has yet to be fulfilled, as there is a need to connect theory and concepts to the realities, challenges, and opportunities of the lives of citizens, under diverse circumstances. In this perspective, we argue that the concept of energy citizenship and its potential for contributing to low carbon transitions should be studied within a research framework that aims to produce transformative knowledge. We also introduce such a new transdisciplinary framework for creating transformative knowledge to explore and address questions relevant to the concept of energy citizenship. Our framework aims to produce knowledge that can be used to mobilize decarbonization actions for both individuals and collectives, by: (i). integrating different scales of analysis and action, i.e., at individual, collective, and national/ regional/ global levels, (ii). reconceptualizing the role of research and researchers, and finally, (iii). striving to be inclusive in a meaningful and innovative way.

1. Introduction

The European Union (EU) is at the forefront of implementing a vision to limit global temperature rise to 1.5℃, grounded by the Paris Agreement on Climate Change and the Intergovernmental Panel on Climate Change (IPCC) 1.5º special report (IPCC 2018). In pursuit of this goal, the EU has set out a net-zero greenhouse gas emissions (GHG) target by 2050 (EU 2018). The European Green Deal and the Just Transition Mechanism, along with the Clean Energy for all Europeans Package, outline policy pathways towards this target, emphasizing the need to transform the paradigm of energy use and the role that citizens can play in decarbonizing the energy system (EU 2019a, 2019b, 2020). To this end, structural changes promoting energy services that will prioritize social justice and mobility are of utmost importance, now more than ever. The role of citizens to help realize such an ambitious goal has been acknowledged within EU's strategic and legislative framework. Yet, which citizens to involve in this process, how to do so fairly and effectively, and when to involve them, remain unclear to experts and policymakers alike (Lennon et al. 2019). The importance of the role that citizens can and will play in the energy transition can be witnessed by the emergence of the concept of "energy citizenship" during the past few years. While an unanimously agreed upon definition of the concept is elusive, Devine Wright (2007, p. 72) provides a broad definition of energy citizenship that is useful as a basis: "*a view of the public that emphasizes awareness of responsibility for climate change, equity and justice (…) and the potential for (collective) energy actions*". Campos and Marín-

Gonzalez (2020) further elaborate that "Energy citizenship offers a background to approach different ways in which citizens are becoming actively involved in the energy transition, and engaging politically, either as consumers and users, by participating in protest and support movements, and,..as prosumers." (p. 1)

Varying forms of energy citizenship have emerged (and continue to emerge) within the energy domain, influenced and shaped by the socio-political, economic and cultural specificities found in particular cases. Some emphasize a normative perspective focused on responsibilities and obligations, while others concentrate on rights, arguing for more inclusive and participatory energy systems (Wahlund & Palm, 2022; Wewerinke-Singh, 2022). At the core of these definitions is a reconceptualizing of the predominant representation of energy – as commodity – to more inclusive and equitable understandings including as both an ecological resource, a social necessity and a service to sustainable development. Lennon et al., (2020) highlight efforts by Devine-Wright (2007) to reactivate Stern and Aronson's (1984) analysis of how energy is often delineated along four key representative constructs. They comprise: 1) energy as commodity; 2) energy as ecological resource; 3) energy as social necessity and basic right, and 4) energy as strategic material. While energy as commodity has remained the normative paradigm for the last one hundred years or so (intrinsically linked to the evolution of the hydrocarbon economy), other representations are beginning to challenge this perspective (see *e.g.*, the discourses on energy justice, energy democracy and energy citizenship), most notably in terms of ecological imperatives and the underlining issue of social necessity. This is already impacting how people view and use energy and will in turn see the realization of new energy behaviors and practices as the energy transition deepens. However, the commodity paradigm, itself situated within doctrinaire neoliberal approaches, has led to a coopting of the transformative language associated with those other representations of energy. This has led to a fracturing of definitions and understandings of energy citizenship that, if not addressed, will most likely continue to hinder its transformative potential. Scientific literature has shown that citizens do not always see their participation and the role of democracy as playing an important role in the energy market (Ruostetsaari 2017; Lennon et al. 2019). This is commonly attributed to citizens who have a limited capacity to be involved in the energy transition, limiting citizen engagement (Beauchamp and Walsh 2021). Moreover, this limited citizen engagement does not necessarily result in meaningful changes in behavior. Much like the spectrum of experiences and expressions of citizenship we see with the democratic project more generally, a consolidated understanding of the concept may help collective efforts to achieve the energy transition goals required to maintain the IPCC's 1.5° pathway needed to offset runaway climate change. Where energy citizenship may ultimately contribute the most to bringing about a significant societal shift is in helping to recalibrate diverse citizens' understanding of the role energy plays in society. The transformative potential of the concept, however, is substantial and can be realized across several societal scales; from reconfiguring people's expectations of energy (derived from their collective and individual perceptions, experiences and relationships with the energy system), to the policy making arena where the rights and obligations made to citizens are ultimately formulated and expressed.

Improving the quality of interaction between policymakers and citizens can bolster individual engagement in the decision-making process, and, therefore, redefine social inclusivity as a basic characteristic of the energy transition. This interaction can be improved through multiple actions, such as by enabling discussions between relevant decision-making stakeholders and local citizens, characterized by social inclusivity and openness. It also entails providing citizens with support, knowledge and resources so that they are better able to initiative individual or collective actions within their own communities. Bringing citizens together with decision-makers may also empower citizens to participate more actively in the decision-making process. Pragmatically, the feasibility and effectiveness of interventions designed to support the energy transition may also be improved by including a diversity of perspectives at the start of policy processes. In addition, the interaction between the key players in the energy sector and citizens highlights the different scales of the decision-making process: the collective and the individual, of which can feed into local, regional, national and global decision making. These scales of potential action need to be reconciled to create a unified force driving the energy transition. This can be done, for example, by better understanding the role of collective decision-making in the adaptation of new technologies and directly working with citizens to empower them to collaborate and cluster around the use and adaptation of new technologies (Biresselioglu et al. 2020). From this perspective, we introduce how a transdisciplinary framework for creating transformation knowledge can be developed to explore and address the aforementioned issues, and, in particular, how the concept of energy citizenship can be defined, modelled and operationalized for the energy transition. We do this by introducing the aims and design of a Horizon 2020 project "Energy Citizens for Inclusive Decarbonization" (ENCLUDE). We propose that the concept of energy citizenship and its potential for contributing to the energy transition should be studied within a transdisciplinary research framework that aims to produce transformation knowledge.

2. Creating transformation knowledge for energy citizenship

ENCLUDE seeks to create a combination of three knowledge types: 1) system knowledge, 2) target knowledge and 3) transformation knowledge. System knowledge is knowledge that seeks to explain what a system is, how it works and why it works that way. It is the type of knowledge most associated with "Mode 1" science (Gibbons et al 1994), in which empirical observations or conceptual developments aim to explain various phenomena. Target knowledge is information that can be used to set goals for society, though it does not address how those targets might be reached. Much modeling activity, for example, makes use of system knowledge to create target knowledge, which is then used to develop or choose between policies. In the context of sustainability and global change, transformation knowledge has been defined as knowledge that creates options for change (Pohl and Hirsch Hadorn 2007) taking into account established technologies, regulations and practices. It has also been defined as knowledge of the ways and means of practically realizing decisions related to societal problems (Jahn et al. 2012) and "integrated knowledge about conditions for socio-ecological transformations and knowledge about the practicability of concepts for goal-oriented actions" (Becker 2002). The production of transformation knowledge is one marker of transdisciplinary research (TDR) that moves beyond the boundaries of traditional research approaches from "Mode 1" to "Mode 2" science (Gibbons et al. 1994). Mode 2 science "engage(s) with a wider system, to articulate … possible pathways for transformation." (Marshall et al. 2018). In essence, transformation knowledge is useable knowledge to secure and sustain inclusive improvements in human well-being (Clark et al. 2016). The field of TDR proposes that this can be done when research is motivated by societal problems, focused on enabling mutual learning amongst researchers between disciplines and with societal actors outside of academia, and creating knowledge that is solution-oriented (Lang et al. 2012). In the case of the energy transition, this is knowledge that could contribute to guiding individuals, collectives and institutions for rethinking how energy is used and produced in order to support processes of inclusive decarbonization.

The challenge of matching the context and scale of decision-making

An overarching challenge of creating knowledge that is useable for the energy transition and related to the concept of energy citizenship is to match the context and scale of decision-making with available insights emerging from a range of disciplinary perspectives. Much of the knowledge currently available are not for the scale in which they could be directly applicable to local decision-making. For example, many integrated assessment models projecting decarbonization pathways are simulated at national and global scales and are designed with aggregated datasets. Their model output is not necessarily reflecting changes that are happening at finer spatial scales, for example, in specific communities or regions. However, (regional/EU and national) energy policies can rely on insights generated from these top-down models to evaluate the technological and economic feasibility of climate goals. This likely creates a mismatch between the feasibility of certain pathways for meeting global goals and the availability of local means of action. The need to match the context of decision-making with the appropriate scales at which available knowledge is being generated, then, requires acknowledging two specific challenges, building on Wilson and Dowlatabadi's (2007) review article of decision models and residential energy demand.

Nesting and connecting scales of analysis

First, nesting and connecting the scales of analysis related to studying energy behavior is required to reconcile the contexts of decision-making and the scale at which data is being collected. The need to connect these scales has been recognized for decades by scholars, but much remains to be done (Sanstad and Howarth 1994; Gibson et al. 2000). Having differences in the scales of analysis is anchored not only in differences in methodology but is fundamentally directed by assumptions of which entity might be the agency for change. Fields of study placing the individual at the center of their analysis, for example, include utility and behavioral economics. Social psychology and cognitive science approaches to studying energy behavior consider the influence of contextual and collective factors in individual choices, but primary agency is still studied at the individual level (Wilson and Dowlatabati 2007). Technology adoption and diffusion theories for understanding innovation are also centered on understanding the influence of attributes of an innovation on individual attitude formation (i.e., technology adopters) (Loorbach 2010; Clausen and Fichter 2019). These diffusion of innovation theories (i.e., multi-level perspective theory, transition management framework) are based on the theory of planned behavior (TPB) in which attitudes shaped by personal values and the perceived social norm are thought to lead to an intention to act, predicting behavior (Ajzen 1991). The sociological orientation of decision-making related to energy, on the other hand, shifts the focus of decision-making outcomes from individual choice to a confluence of systemic factors, with the individual choice being strongly influenced by structural norms and rules. This perspective, however, also acknowledges the influence of individuals on systems over time. Approaches to this study of collective behavior can be exemplified by the socio-ecological systems approach (SES) (Ostrom 2007, 2009) and the institutional analysis and design (IAD) (Ostrom 1990) in the field of political economy, but also at the intersection of sociology and anthropology (i.e., Energy Cultures Framework and social practice theory). Rather than individuals making decisions about consuming energy and the resources to creating energy, the demand for energy is an indirect outcome of meeting needs, like comfort and cleanliness, that are systemically configured. A longer time horizon accompanies this systemic view of behavior. Interventions focused on individual agency, on the other hand, target psychological variables affecting behavioral change in the short term (for example, Fischoff 2005; Gregory et al. 1992). Exploring how these various scales of agency may be most appropriate for specific contexts of energy decision-making is a critical next step for linking together these rich perspectives through nesting decision-making models.

Recognition of heterogeneity

Second, matching relevant scales of knowledge and models about energy behavior to appropriate decision-making contexts requires a recognition of heterogeneity in various contexts in which decisions are being made. Empirically, energy use and the challenges that individuals and households face related to the wider energy system vary even when differences in contextual factors are accounted for. Understanding decision-making at different scales is a critical first step. Implementing a nested decision-making framework already incorporates heterogeneity, since emphasis is placed on a particular set of individual and collective variables depending on the scale that is being studied. Thus, the recognition of differences between scales helps to take into account the heterogeneity present within each scale of analysis, since behavioral patterns and responses will vary across a target population for an intervention. This recognition also has implications for justice and the inclusiveness of interventions, especially important when considering the concept of energy citizenship. To address this, interventions designed based on aggregated analyses must be questioned, in favor of a diversity of approaches. In practice, this means that a variety of stakeholder perspectives should be incorporated into the knowledge production process, including insuring inclusive participation in research processes and in setting up natural experiments in an adaptive management. Figure 1 illustrates how we bring together elements of scale of knowledge and models for energy decision making (elaborated in section 3).

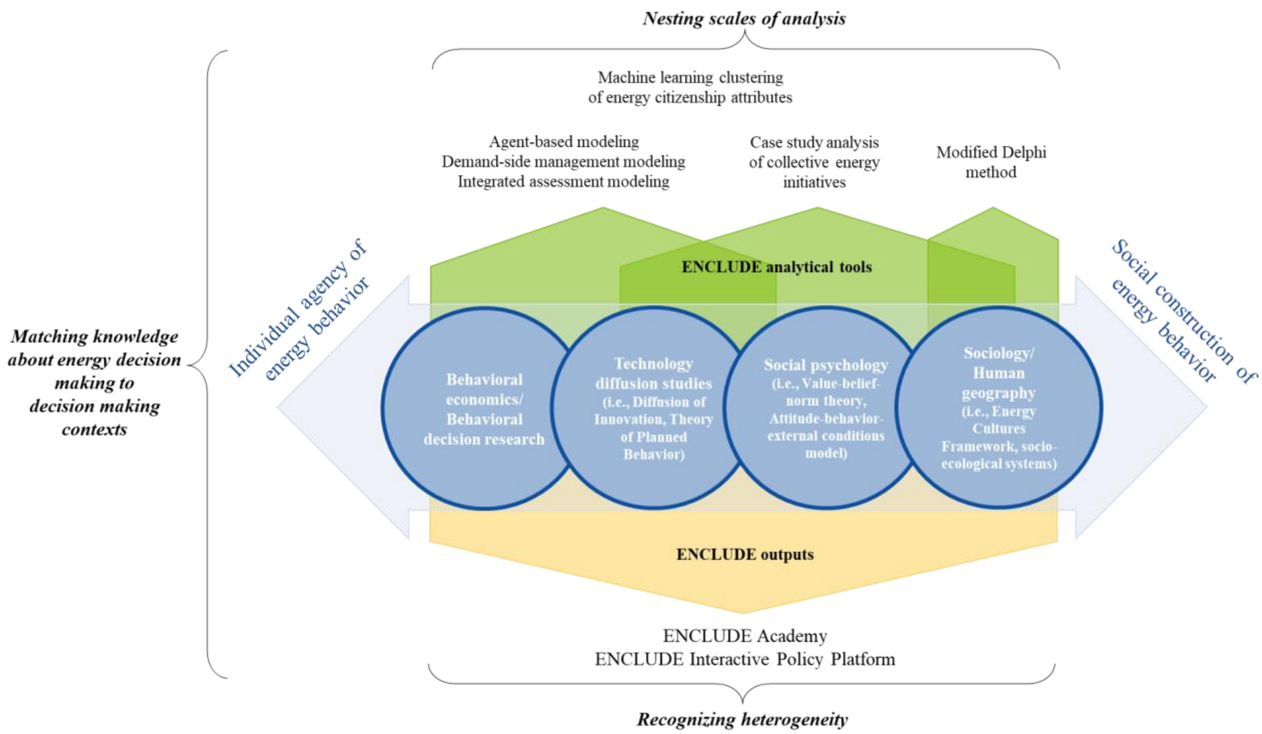

Figure 1 Spectrum of individual-systemic view of energy behavior and ENCLUDE's approach to integrating scales and recognizing heterogeneity in cutting across these disciplinary approaches

Through the selection and sequencing of the analytical methods and tools implemented, as well as through the design of its project outputs for specific audiences, ENCLUDE seeks to engage with these core challenges of scale and heterogeneity to create useable knowledge for the energy transition.

3. Methods for creating transformation knowledge

The concept of energy citizenship provides a unique lens through which to study energy behavior at different scales. Through energy citizenship, the public is conceived both as individual stakeholders in the evolution of the energy systems, as well as representing a set of community values that can be harnessed for change (Beauchampet and Walsh 2021). In order to realize the transformative knowledge approach in ENCLUDE, we use a variety of qualitative and quantitative methods that are aimed at matching knowledge outputs with the contexts of decision-making for the energy transition. These methods contribute to: (i) integrating different scales, i.e., individual, collective and national/global scales, for energy citizenship in the data collection and analysis processes, (ii) reconceptualizing the role of research and, finally, (iii) striving to be inclusive in a meaningful and innovative way.

3.1 ENCLUDE analytical tools

The proposed framework uses a qualitative and quantitative mixed-methods approach that is determined by its objectives for the project. In ENCLUDE, we use this methodological pluralism approach in order to address the challenge of connecting the scales of analysis by accounting for which methods might be relevant at various scales:

- Individual/household/collective scale: the Modified Delphi method (individual), case study analysis (collective scale), agent-based models (ABMs- individual), demand-side management models (DSMs- individual household), machine learning (ML) clustering.

- National/global scale: desk research of existing databases and/or policy documents across scales, machine learning (ML) clustering (which is based on insights collected at the individual and collective scales) and, finally, integrated assessment models (IAMs) (national/supranational scale) (See Figure 2).

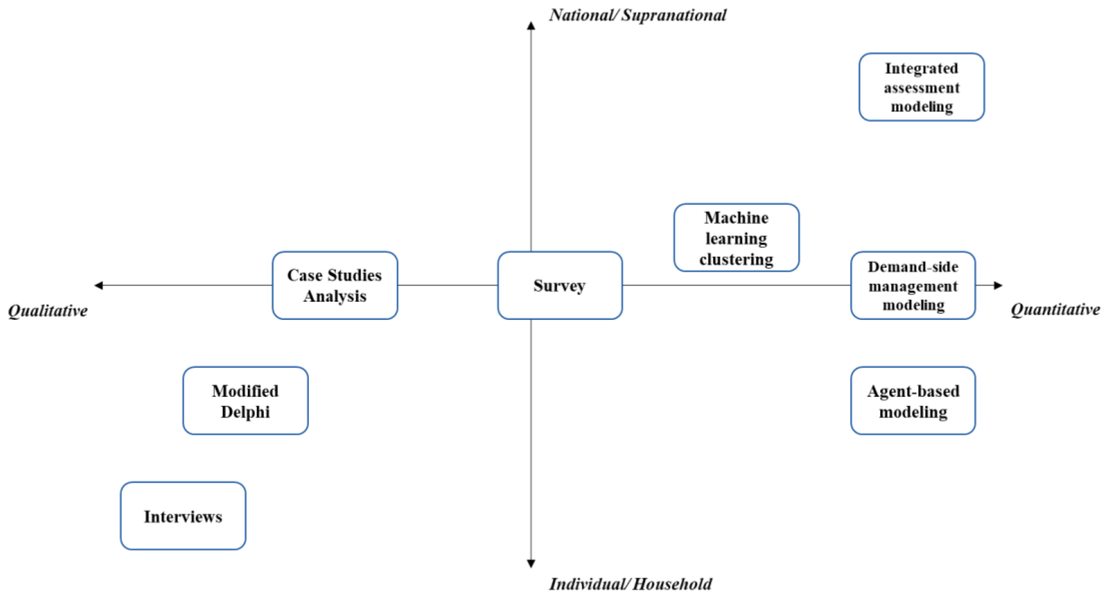

Figure 2 Matching of ENCLUDE's analytical tools with scale and types of methodology approaches

Individual scale

For the individual scale, the modified Delphi method lends itself to both the data collection and analysis phases. Revez *et al.*, (2020) adopted the technique for use beyond a forecasting instrument by the inclusion of elements of participatory action research. The resultant modified Delphi approach is a form of an asynchronous dialogue, which seeks not to see what *will be* but rather represents an envisioning tool that collaboratively seeks to explore the way an object or phenomenon *could* or *should be*. Such modified Delphi panels facilitate capturing individual experts' perspectives on a phenomenon—in this case, the relationship of the citizenry with the energy system and climate change mitigation efforts in the last decade (Moss et al. 2010)— to examine their views on how a phenomenon might develop.

Also at the individual scale, two bottom-up energy system models are employed to simulate with high temporal resolution the individuals' behavior, lifestyle changes and demand needs. The models employed under the framework are an ABM modeling the diffusion of social innovations, and a DSM model simulating the energy demands of individual households, incorporating an individual's behavior and lifestyle changes. The combination of these two models provides the benefit of essentially capturing the end-users' perspective and needs with high detail and resolution. The bottom-up findings from the Delphi method, for example, can provide insights to different types of behavior categories for energy demands, and could be compared to the outputs of the data-driven machine learning (ML) clustering algorithm (discussed later). Together these can serve as inputs to creating different scenarios of energy citizen behavior in the integrated assessment models.

Collective scale

For the collective/organizational scale, case study data collection and analysis (65 case studies) will be collected and synthesized to study energy citizenship from a group-centered sociological perspective, to identify the most important processes and factors affecting the emergence and consolidation of collective energy citizenship. This raises the need to link theoretical frameworks addressing various collective and individual aspects to explain energy related behavior. These are the Energy Cultures Framework and the Socio-Ecological Systems Framework. While the Energy Cultures Framework is primarily used for the analysis of energy relevant behavior for specific energy-related initiatives, the Socio-Ecological Systems (SES) Framework is a general framework, originally designed to provide a diagnostic tool to identify the sustainability of complex systems at different spatial and temporal scales (Ostrom 2009). The SES approach seeks to help researchers identify the most important factors of a diversity of socio-ecological systems in order to “move beyond panaceas” and simple solutions which support the sustainability of these systems (Ostrom 2007). The aim of a general SES framework is to provide a common set of potentially relevant variables to use in the study of diverse systems such that knowledge regarding the governance of resource systems can be accumulated. Consequently, it is hoped that this accumulated knowledge would inform the design of policies that are sensitive to context in which they would be applied (Ostrom 2009). The SES framework is structured around four “first-level core subsystems” that affect the functioning of almost all socio-ecological systems, including: (i) resource systems; (ii) resource units; (iii) governance systems; and (iv) actors/users. These subsystems are then studied within the context of the social, economic and political settings and related ecosystems. Within these subsystems, there is a choice of a second-level of variables whose identification grounded by the empirical investigations of common-pool resource use over decades (Ostrom 1990). These second-level variables serve as a starting point for researchers for which key factors to study when trying to diagnose the factors leading to varying degrees of sustainability within a system.

A challenge and opportunity embedded within the design of SES framework is that there is no set protocol or instructions for how to implement it (Schlager and Cox 2018). To avoid idiosyncratic approaches to this implementation, a clear theoretical underpinning and guiding research questions are needed to explain why particular second-level variables are selected and which are left out. An existing example of the implementation of the SES framework for the study of integrated community energy systems (Acosta et al., 2018) has been based, for example, an engineering design process, where the emphasis is on creating a guidance for how to best govern the processes of creating energy cooperatives. Within the scope of ENCLUDE, we underpin the four subsystems of the SES framework with the Energy Cultures Framework (Stephenson et al. 2010) and the Social Identity Model of Pro-Environmental Action (SIMPEA) (Fritsche et al. 2018). Examples for relevant second-level variables (within the actors/users subsystem) for studying collective energy initiatives are the interaction between actors (the way of communication, conflicts, decision-making, etc.), presence of leadership, knowledge of the SES, collective-choice rules, existing norms, size of the system, etc. The Energy Cultures Framework thus assumes that a specific observable energy related practice or behavior is connected to a certain pattern of cognitive norms, and material culture. With these frameworks we thus assume that the establishment of an energy citizenship initiative and its consolidation depend on aspects of cognitive norms, material cultures and concrete energy practices. These complementary frameworks can be applied when synthesizing findings from case studies as they provide a more specific delineation of variables which link up individual and group energy practices and norms, as well as governance of energy systems. This approach allows us to create an interdisciplinary and multi-scalar understanding of the consolidating and hindering factors of successful collective energy initiatives.

National//Supranational scale

Next to this case study analysis, a data-driven machine learning (ML) clustering algorithm will be applied to recognizing and categorizing energy behavior patterns at both the individual and collective scales, and extrapolating to national and supranational scales. Several attributes could be considered for clustering citizens and collectives such as electricity consumption, heat demand, sociodemographic and psychological attributes such as age, income, education, motivation, awareness about climate and readiness to embrace energy citizenship actions, and, importantly, the key needs that citizens have in relation to the energy system (i.e., energy access for electricity or cooking, energy security, energy efficiency, energy reliability, access to renewable energy), as defined by the Sustainable Development Goal 7 indicators for affordable and clean energy (UN 2021). Citizen clusters for decarbonization are not necessarily groups of citizens with common demographic characteristics; rather, they may involve demographically diverse groups sharing common characteristics of energy behavior, based on their needs in relation to the energy system. Clustering in both citizen and collective levels could lead to insights for policy makers by identifying potential decarbonization opportunities based on these needs. The results from the ML clustering can be shared with stakeholders and compared to results from the ABM, DSM output, and frameworks as well as some to have a ‘sanity’ check. This is to ensure that inherent biases are not built into data-driven clusters or that we have blind spots due to missing data points that might not have been picked up by the algorithm.

After deriving data-driven clusters calculating their potential decarbonization impact would require modelling and upscaling of their energy behavior in relation to individual and collective energy needs. This would be realized by using the outputs of the clusters to inform the energy system models mentioned previously, following an iterative process where the inputs to energy system models will be recalibrated to accommodate outputs of the data-driven clusters. Energy system models would accordingly be used to estimate the aggregated reduction of carbon emissions from upscaling specific actions that citizens take towards decarbonization. For this upscaling to a national/supra-national level, the micro-perspective of energy systems models, alongside the clustering outputs, will be coupled with an IAM model to implement a deep-dive assessment of the decarbonization potential and climate implications of social innovations. At a national level, the focus will be on aggregated emissions, key climate impacts and adaptation requirements. This will allow studying in detail the impact of the concept of energy citizenship on several important aspects: the remaining emissions gap that needs to be narrowed and eventually closed; the costs, challenges, opportunities, and benefits of doing so through enhanced mitigation action; and the further policy agenda around implementing the mitigation actions necessary for achieving high-level decarbonization. Following the modelling and upscaling of the clusters for decarbonization, a number of "what if scenarios" relevant to the identified clusters of citizens will be developed to investigate different routes to reach decarbonization targets.

3.2 ENCLUDE transformation knowledge outputs

While the frameworks and model suites help us to better understand energy citizenship and contributes to scientific conceptualization (system knowledge) and to setting policy agenda (target knowledge), another important part of the project is to promote the co-development of transformation knowledge for decision makers (energy citizens and policy makers). We are designing the ENCLUDE Academy for Energy Citizenship Leadership based on the insights from our approach and integrating knowledge from past projects, stakeholders, and documentation of effective collective action, 50 citizens (from diverse regions and backgrounds, with the focus on those in regions with little energy transition activity) will be trained to become "energy citizenship leaders" through an action-based, collective learning program. These community leaders will re-establish the program and deliver this collective learning curriculum in their own communities to train more leaders. They will be supported in their efforts through the materials developed by the project, through training modules and a playbook for collaborative decision-making. In addition, the aim of the training for the Academy of Energy Citizenship Leadership is to encourage citizens to launch, raise awareness for or support existing decarbonization initiatives.

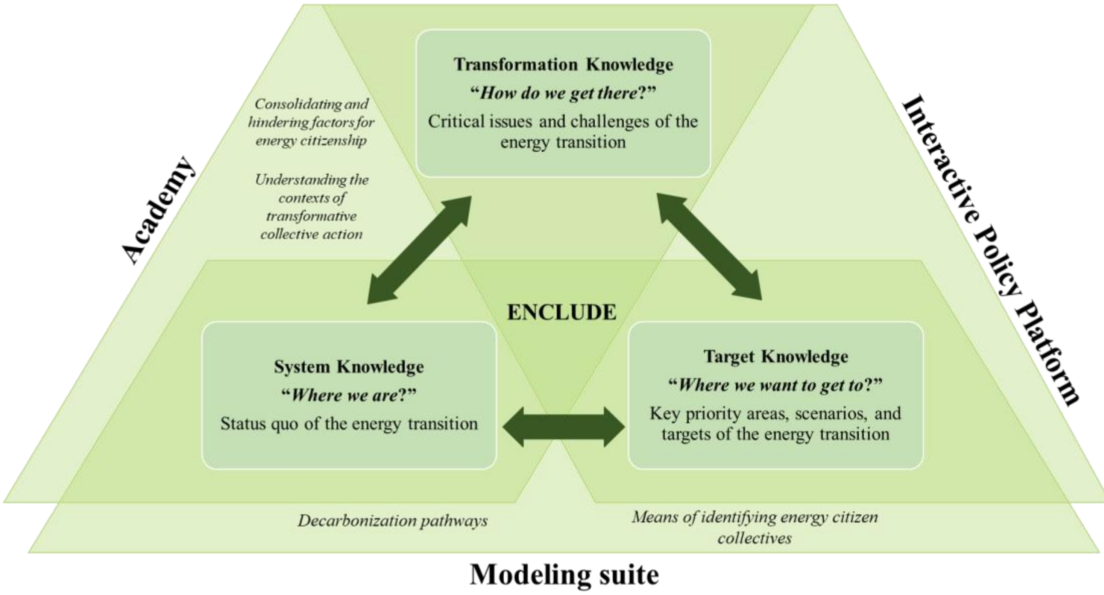

Figure 3 Knowledge outputs of ENCLUDE mapped to the three knowledge types (system, target, transformation knowledge)

We are also developing the Interactive Policy Platform will provide policymakers with useful insights regarding the conditions and the contexts within which energy citizenship can lead to high decarbonization, which will be open access and publicly available. The active involvement of stakeholders in the science-policy-business-citizen learning dialogue process will provide a reality check on the assumptions and approaches, as well as ensure high policy relevance. This platform will not provide blanket solutions but will be tailored to the energy citizenship typology (informed by our empirical work discussed above), within a wider range of contexts, and to different energy citizens and ground truths.

In order for ENCLUDE processes and outputs to be inclusive, applicable, and scalable, three methods are mainly used. First, the empirical work prescribed in our framework is based on creating a large and active network of organizations and stakeholders working on different aspects of energy citizenship, for instance, energy communities working with renewable energy, as well as those concerned with energy poverty. While such a network allows for the collection of case studies, it can also establish communication channels allowing for mutual learning and continuous exchange on applications of energy citizenship. Second, our framework aims to disseminate its produced knowledge through peer-exchange programs and educational materials for citizens and other stakeholders, improving the applicability of research through dialog. Third, the research products of our framework are aimed to be disseminated through interactive and customizable web platforms, emphasizing the need for tailor-made information for reaching a diverse set of stakeholders and adapting to their needs and different contexts. All these methods will ensure research results that can be relevant, user-friendly, and useful to stakeholders.

ENCLUDE confronts the challenge of inclusivity by including NGOs from various contacts at an early stage of research and problem framing—through inclusive joint problem framing. ENCLUDE also confronts the high costs of participation by identifying the catalysts in communities such that widespread engagement can be sparked by those who belong to the community. ENCLUDE also seeks to give voice to a multitude of perspectives in creating a path forward to change.

4. Potential limitations, implications and outlook for adapting the transformative knowledge approach for energy citizenship

Despite decades' worth of quantitative and qualitative research on decarbonization (Sovacool 2014; Stoddard et al. 2021; Peñasco et al. 2021), wide stakeholder engagement in such a broad and diverse research topic remains challenging (Mach and Field 2017; Slater and Wiek 2010). While transdisciplinary methods offer a solution by emphasizing co-creation with stakeholders throughout all research stages, they have been usually applied in small-scale projects or with small groups of stakeholders (Lang et al. 2012). One of the challenges in working with stakeholder is that this increases the amount of time required for scientific research outputs. Additionally, not all qualitative insights from stakeholder can be included in models due to data gaps. Thus the qualitative framework can help to provide insights where models cannot cover. The main novelty of our framework lies in the use of inclusive, interdisciplinary and transdisciplinary research paradigms to explore the energy citizenship concept while aiming for high applicability of research results. Through this framework, relevant stakeholders of decarbonization such as citizens, civil society organizations, policymakers, and industrial representatives participate through a multitude of roles: co-creators, evaluators, and final users of research products. In establishing and maintaining these multiple roles, communication and dissemination activities play an instrumental role. Working with stakeholder throughout the research process means that this alters the outcomes of our research. This would require flexibility in our research approach and to design outputs (e.g. in our academy and policy platform) that are relevant (and different) for scientific, policy and societal stakeholders.

5. Conclusions

The energy transition represents one of the most challenging social dilemmas of our time. This is a transformation that requires not only overcoming technological challenges, but even more so, overcoming ingrained ways of engaging with an energy system based on fossil fuels, and confronting deeply embedded power and structural components, which have been built around a set of assumptions of energy security and availability that is rapidly changing. In order to overcome these challenges, research itself must reach beyond disciplinary perspectives, separating insights that are available for various scales of individual, collective and system behavior. ENCLUDE improves knowledge transfer through integrating individual and collective scales of knowledge application, by making use of qualitative and quantitative methods for data collection. We apply by social science insights from the Energy Cultures Framework, Socio-Ecological Systems (SES) Framework and the Social Identity Model of Pro-Environmental Action (SIMPEA) to help frame and analyze empirical data collected from 65 energy citizenship case studies. These results are complemented with a model suite that provides bottom-up insights from ABP and machine learning clustering up to collective scales can increase the resolution of data for modelling, scaling up through IAM, and also with quantitative modelling structure and logic. Overall, our qualitative insights from stakeholders and quantitative outputs from models give us a more comprehensive, yet detailed picture of the potential for energy citizenship. The project also sets up a platform for iterative dialogue between stakeholders and citizens, early communication and meaningful consultation in planning process between and within stakeholder groups, fair and inclusionary planning process for specific projects, increased control and opportunities for self-sufficiency and co-production through material participation, public dialogues on energy issues. ENCLUDE seeks to contribute to bringing these cross-scalar insights together and to bringing the EU one step closer towards energy freedom with the help of all its citizens.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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