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***Abstract*—Citizens are expected to play a significant role to the current energy transition in Europe, such as through prosumerism and collective initiatives for energy efficiency. While there are many platforms for domestic energy analytics and for engaging citizens and transition stakeholders on energy topics, context-specific information is frequently lacking. This article outlines the development of an Interactive Policy Platform that aims to provide contextualized, impact-driven, and ready-to-use information on the role of citizen initiatives in the energy and low-carbon transition in Europe. Specifically, it will help researchers, policymakers, and citizens to explore different dimensions of energy citizenship, understand the decarbonization potentials of diverse clusters of citizens, and identify the conditions under which citizen-led energy initiatives are currently operating. The Platform will be co-designed together with a sample of its future users, ensuring the usability of its interface and the relevance of the provided information. Ultimately, the Platform is envisioned to help transition stakeholders understand and support initiatives related to energy citizenship around Europe, thus contributing to the EU's promise of a just and inclusive decarbonization.**

Keywords—energy transition, energy citizenship, stakeholder engagement, interactive platform, climate-economy modeling

I. Introduction

Many European countries are in the process of significantly transforming their energy system [1]. These energy transitions have multiple drivers including the reduction of greenhouse gas emissions in the context of climate change mitigation [2], concerns of energy security and affordability [3], and geopolitical events such as the recent conflict in Ukraine [4]. Traditionally, the main actors on energy policy have been policymakers, researchers, and the industry. However, there are many calls for increasing the direct influence of the public in energy-related decision-making [5]–[8]. A prominent method to conceptualize the role of the citizens in the energy transition is based on the idea of energy citizenship [9]. Among the many definitions that exist in the literature, energy citizenship can be understood as a perspective that focuses on a sense of "responsibility for climate change, equity and justice (…) and the potential for (collective) energy actions" [10]. Energy citizenship is a broad concept that can include many different interactions of the citizens with the energy system. Examples include energy-related education, such as being knowledgeable of energy supply options and their impacts; active consumerism, where consumer power can be used to affect energy markets; and socio-political aspects, such as concerns about energy poverty and justice [8]. In addition, energy citizenship can have a collective dimension such as by participating in energy communities where citizens can be also energy producers in addition to being consumers (i.e., "prosumers") [11], [12]. Nevertheless, engaging citizens in these topics can be often challenging, among other reasons due to the complexity of energy system and markets and the low interest of the citizens [13].

In an effort to increase citizen engagement in energy and decarbonization topics, interactive platforms have been often used during the last decade [14], [15]. Existing platforms have been used to provide energy education, ask for user feedback about different aspects of the energy system, and provide tools for supporting energy-related decisions, such as how to renovate one's house for increasing energy efficiency [16]. With the recent surge in the use of mobile devices, many of these interactive tools have been developed as mobile applications and included elements of gamification to increase engagement [17]. The Earth Hero application is a prominent example of using a game-like interface to nudge users towards climate- and energy-conscious actions, such as choosing a low-carbon electricity supplier, taking holidays closer to home, and reducing food waste [18]. Other apps focus on facilitating these actions, for instance, the WasteApp that helps users to locate recycling bins in their city, while there are also numerous board games that sensitize users to energy issues [17]. Despite the variety of apps, there are still few studies evaluating whether these apps are effective on

changing behaviors, while even existing studies may show conflicting results [17], [19]. Another problem is that the context of the citizens may not always be anticipated by the app designers. For instance, the Earth Hero app may suggest reducing car usage in places where public transportation may not exist or may be inefficient. Additionally, while many of these tools are tested by their final users, truly co-designed and user-centered processes are rarely the case [19].

In addition to citizen engagement, interactive platforms and apps have been used to disseminate information on the energy transition to many other users, such as policymakers, industry representatives, and other stakeholders. Prominent examples include the IIASA scenario explorers [20] that allow users to navigate through the global scenarios for climate change mitigation that inform the assessment reports of the Intergovernmental Panel for Climate Change (IPCC). As these reports form the cornerstone of low-carbon policies for many countries and companies [21], understanding and extracting information from them is instrumental. The SENSES project aimed to further improve the usability of these scenarios by providing interfaces with scenario-derived information that are tailor-made to policymakers and financial institutions [22]. Apart from tools providing information at a global level, many tools have been built for exploring the future energy system for different countries and the European Union (EU) and for understanding the impacts of different energy alternatives (e.g. [23]–[25]). Nevertheless, most of these platforms focus on researchers and high-level policymakers [26], despite calls for extending them to respond to the needs of regional and local policymakers [22]. While numerous decision support systems have been developed to assess and support the planning of local energy initiatives (e.g., [27], [28]), most of these systems do not link local assessment with global- or national-scale requirements. Furthermore, many global or national scenarios are focusing on large-scale technological and policy options for transforming energy supply [29]. In contrast, few of these scenarios are based on measures to reduce energy demand and small-scale actions that could be taken by energy-conscious citizens [6].

The EU Horizon 2020 ENCLUDE project aims to explore the role of energy citizenship in decarbonization pathways for Europe and operationalize it accordingly in order to catalyze decarbonization action across the EU [30]. Towards this goal, ENCLUDE project will develop an Interactive Policy Platform to support strategic decisions about *how*, *when,* and *with whom* to engage within the energy transition. The platform will comprise an online collection of tools developed by the project, designed to be easily used by stakeholders of the transition. The platform is envisioned to provide impact-driven and ready-to-use knowledge, by offering contextualized information that is tailor-made for policymakers, citizens, and researchers and by ensuring that this information is useful and comprehensible. This increased usability in the platform will be ensured through a rigorous co-designing process along with a sample of the platform's audience. The audience is divided into three main categories: 1) policymakers at a national, regional, and local level (with emphasis on the last two sub-categories), 2) citizens that are already engaged or planning to become engaged in energy initiatives and energy communities, and 3) scientists and researchers working on topics relating to energy, citizen engagement, inclusivity, energy poverty, and more.

Here we present the conceptual design of ENCLUDE Interactive Policy Platform along with its envisioned development process. The aim of this article is to contribute to the overall discourse of how we can meaningfully operationalize research results on energy topics in order to match the needs and the abilities of their users. First, we present the existing web infrastructure that we will use to build the Interactive Policy Platform on energy citizenship. Then, we elaborate on the conceptual design of the Platform. Finally, we describe the co-designing process that we will follow to develop the Platform together with a sample of its future users.

II. Existing infrastructure: I²AM PARIS

The Interactive Policy Platform will be built on the I²AM PARIS infrastructure [31] that was initially developed during the EU Horizon 2020 PARIS REINFORCE project[1]. The I²AM PARIS is an open data exchange platform that is publicly available[2] and aims to be the most comprehensive portal of modeling information related to climate change mitigation. In contrast to other similar platforms, I²AM PARIS was specifically designed to provide interfaces on modeling and research information that are tailor-made for different stakeholders. These interfaces include interactive data visualizations along with short analyses and discussions of pertinent results. Additionally, the platform provides access to extensive modeling documentation and key modeling assumptions and drivers that were used to produce the results, facilitating their interpretation and transparency. On the latter, the I²AM PARIS was also designed based on the principles of Open Science and FAIR data exchange. Eventually the platform will also provide links to open code repositories, in an effort to contribute towards opening the "black box" of energy and integrated assessment models [32].

Technically, I²AM PARIS is based on the Django Web framework and programmed in Python. In terms of architecture, the platform was designed to handle data-intensive API transactions while keeping high usability standards. While the output data of energy and climate change mitigation models is not approaching the volume or velocity of big data in other fields (e.g., data from sensors and services related to the built environment [33], [34]), they still are challenging to handle, especially by non-modelers. In order to achieve both fast interaction and high customizability in terms of the type and format of results that are available, I²AM PARIS relies on three components. First, there is a main *Backend* component that handles API calls with the frontend and provides schemas for all data entities. Second, API calls are translated to data request parameters which are then sent to a *Data Manager* component that retrieves and processes the required data from the platform's database. Third, the formatted data are sent to the *Visualizer* component where they are used to develop maps and charts which are then shown to the user. These three components will be extended accordingly to handle new data structures, visualizations, and functionalities needed for the Interactive Policy Platform (see Section III).

Currently, the I²AM PARIS platform offers interfaces that are mainly addressed to scientists and policymakers (Figure

[1] https://paris-reinforce.eu
[2] https://www.i2am-paris.eu/main

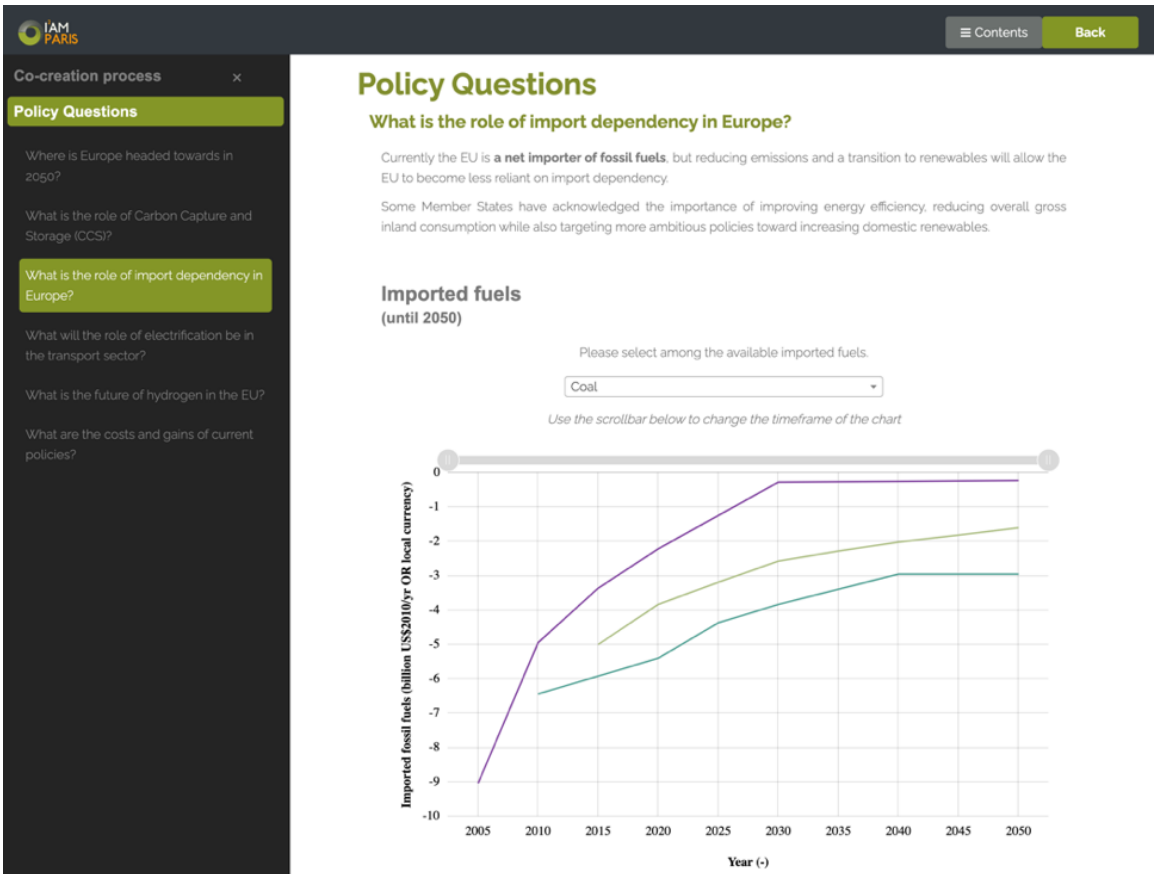

Fig. 1. I²AM PARIS platform, demonstrated here using the Policymaker module

1). Specifically, the platform includes modules that provide detailed documentation for numerous energy and climate-economy models along with information on the input data used in the models. Details about these modules can be found in a previous article on the I²AM PARIS by Nikas et al. [31]. In terms of results, the platform provides two modules. First, an *Advanced Scientific module* that can generate visualizations on all available results while allowing the user to extensively customize the content and format of these visualizations and, also, download all data. Second, a *Policymaker module* that aims to explain modeling results to policymakers by responding to pertinent policy questions using concise and interactive figures along with short explaining texts (Figure 1). The design of all existing modules and the policy questions were informed by multiple workshops with transition stakeholders.

III. Conceptual Design of the Interactive Policy Platform on Energy Citizenship

The Interactive Policy Platform will provide citizens, policymakers, and other stakeholders with useful insights regarding the conditions and the contexts within which energy citizenship can lead to high decarbonization. The Platform will be designed to be easily accessible through a special user interface which will allow users to see the outcomes of models specified for their own communities, regions, or countries. Thus, it will provide customized and contextualized information rather than generalized facts, allowing for increase usefulness and immediate application. Specifically, the Platform will provide interactive results tailored to different typologies of energy citizenship, within a wide range of contexts, and for different clusters of citizens and energy initiatives. Platform users will be able to input their search criteria and energy citizenship context and request relevant outputs, tools, and guidelines. Overall, the Platform will include four different but interconnected modules reflecting the overall work of ENCLUDE project on conceptualizing and operationalizing energy citizenship (see Figure 2 for an outline).

The first module will provide an interactive tool for identifying clusters of citizens that fit on specific criteria relevant to energy citizenship, for instance, habits of energy use and sociodemographic characteristics. The users will interact with the tool by filling quantitative characteristics of the community/citizen group they are interested in. The tool will then present the energy citizenship cluster that best describes their community/group (based on the typology of the subsequent module) and will show an overview of their characteristics for the context of the user. The tool will also prompt the users to learn more details about the decarbonization potential of the selected citizen cluster as well as provide recommendations for promoting the participation of the cluster in the energy transition.

Next, the second module will allow users to explore different dimensions of energy citizenship. These dimensions will be based on a theory-informed typology assembled by ENCLUDE through an extensive literature review and includes diverse aspects such as energy poverty, activism, and agency. The module will present this information through an easy-to-use interface that will first show an overview of all dimensions and their interconnections and will then allow the

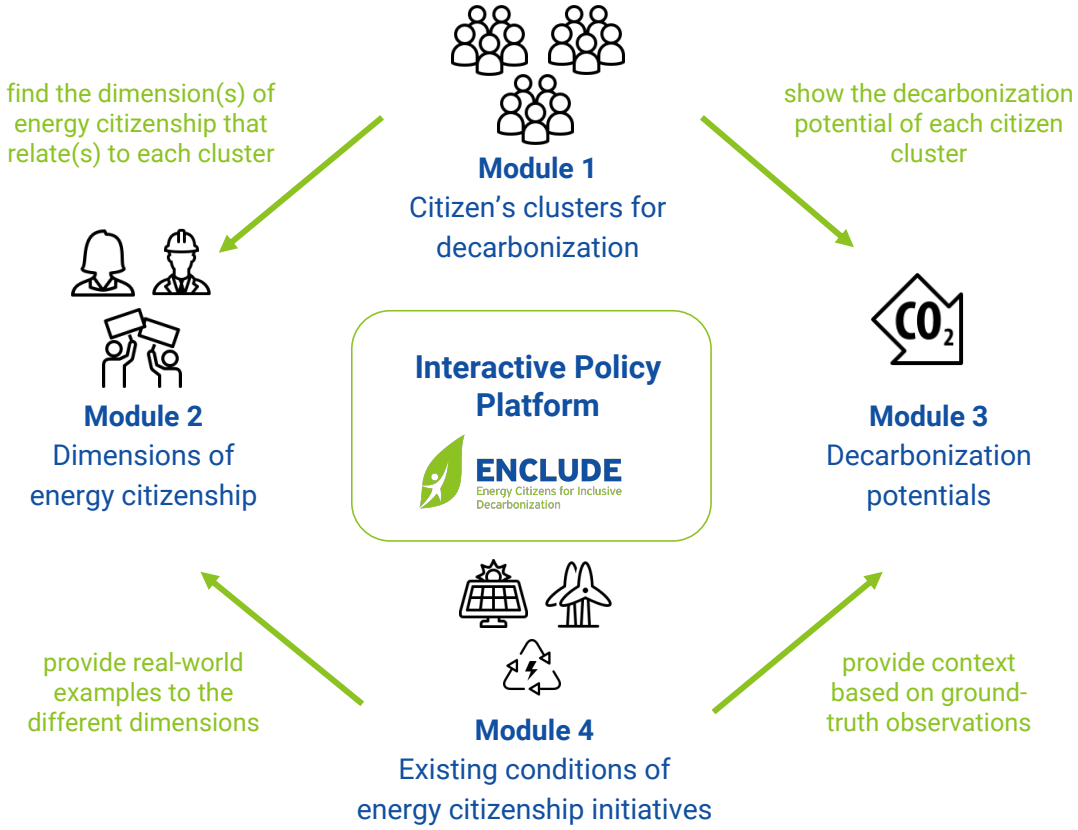

Fig. 2. The four interconnected modules of ENCLUDE's Interactive Policy Platform

users to filter or select the dimension they want to learn more about.

The third module will provide quantitative, context-specific decarbonization potentials based on energy and integrated assessment modeling. The Platform will not only include modeling outcomes but also appropriate data, modeling assumptions, and guidelines for replication. Model documentation will be also provided through detailed individual webpages per model and in the form of a concise interactive infographic, visualizing the main characteristics of all used models. All modeling results and outcomes will be presented in an easy to digest manner for various target audiences, especially citizens and energy communities.

Finally, a fourth module will provide information on numerous case studies for energy communities and initiatives relative to the energy citizenship concept. ENCLUDE will document these case studies through a large survey, with the purpose of identifying "ground-truths" relating to these case studies and understanding the context that existing energy communities and initiatives are already working in. Survey data about the context and operation of these communities will be then anonymized and aggregated for data privacy considerations. Subsequently, the processed data will be shared in the Platform, allowing users to understand the existing conditions around Europe for energy initiatives. In that way, this module aims to complement the research and analysis of the other three modules by anchoring their results to the reality faced by energy initiatives today. The data will be provided through interactive tables, allowing users to filter information on the case studies based on specific criteria. Additionally, an interactive map will be developed to show spatial information about the case studies as well as their location.

IV. Co-designing process

The Interactive Policy Platform will be developed based on the "Quintuple Helix" approach [35]. The Quintuple Helix is an innovation model that aims to help understand the links between knowledge and innovation for socio-ecological transitions by studying the relationships between academia, industry, policymaking, the public, and the natural environment [35]. For the Interactive Policy Platform, this approach will be implemented by communicating tailored outputs to citizens, policymakers, researchers, and other stakeholders and by incorporating their feedback into the Platform. This transdisciplinary approach acknowledges and values different types of knowledges outside of science and research and includes experiences that are valuable for policymaking and for understanding the phenomenon of energy citizenship. Thus, the Interactive Policy Platform will not only include scientific information on energy citizenship produced through the ENCLUDE project, but also feedback provided through stakeholder engagement activities with citizens, energy communities, local, and regional authorities. This inclusive and participatory approach will provide the opportunity to legitimize the Platform by testing it with its future users prior its release and thereby increases its likelihood of use and relevance.

We will integrate co-creation activities throughout the development process of the Platform. Initially, storylines for each user type will be created in consultation with the target

audiences. We will also strive towards an inclusive consultation, ensuring the participation of users with different backgrounds, genders, social-economic status, age, etc. Examples of use cases based on different user profiles are given below.

- **User story for policymakers**: The users visit Module 1 and fill a set of criteria/descriptives about the citizen cluster they are interested in. As part of ENCLUDE's activities, citizens will be clustered based on common characteristics relevant to the energy transition and the different dimensions of energy citizenship, for instance, citizens living under energy poverty or citizens living at rural areas (Module 2). The user is then provided with advice, including an overall description of the 'type' of citizen cluster in the context of energy transition, recommendations on how to interact with cluster, and estimations of its decarbonization potential (Module 3).
- **User story for researchers:** As in the case of policymakers, users from academia and research can access information about different citizen clusters based on filtering. In addition, more advanced users will be able to view and download information about all the dimensions of energy citizenship and available citizen clusters through the first three modules of the new Platform.
- **User story for citizens**: The users first fill in a set of criteria and descriptives about their personal characteristics in Module 1 (e.g., their energy use, habits, whether they belong to an energy community, etc.). The users are then provided with an estimation of their current energy and carbon footprint, adapted accordingly based on the energy community they participate in. Additionally, users are provided with context-specific advice on actions that they can take and (other) communities/initiatives that they can join, along with estimations of the decarbonization potential for these actions.

Based on such user stories, we will develop wireframe and mock designs of the Platform and test them again with potential users through usability design methods such as the "think-aloud" protocol. Depending on the feedback of the users, the Platform design may also deviate from the initial structure shown in Figure 2, which is mostly based on modules of different functionalities. For instance, an alternative Platform architecture may be based on developing unified interfaces for specific user types, following the example of the SENSES project [22]. Apart from testing the design of the platform, testers will provide a reality check on the assumptions and approaches used to present the Platform's outputs and assess the format of these outputs in terms of whether they are useful for their work. For instance, for the user group of local policymakers, we will evaluate whether Platform information is granular enough to be used in their local context. In this respect, a protocol will be developed for guiding the integration of modeling outcomes into the Platform, along with model documentation, appropriate data, and guidelines for replication. After this process, we will design the first operational version of Platform presenting ENCLUDE's research results on energy citizenship. Finally, we will contact a diverse group of citizens, researchers, and decision makers to test the fully operational Platform before its public release.

V. Conclusions

While there are many interactive platforms for stakeholder engagement on energy and low-carbon topics, tailor-made information that reflects the contexts, needs, and abilities of different users is frequently lacking. Through the development of ENCLUDE's Interactive Policy Platform, we aim to provide contextualized, impact-driven, and ready-to-use information on the role of energy citizenship initiatives in the energy and low-carbon transitions in Europe. The Platform will be built on top of the I^{2}AM PARIS, an open data exchange platform that was developed to provide customizable interfaces for accessing and interpreting research and modeling outcomes on climate change mitigation. The Interactive Policy Platform will extend I^{2}AM PARIS by providing modules for exploring different dimensions of energy citizenship, clusters of citizens and their potential contribution towards decarbonization, as well as the existing conditions where energy initiatives are currently operating in. The new modules will be developed based on continuous stakeholder participation from the onset of the development process in order to ensure the usability and the relevance of the provided results. Further studies will document the final design and the development process of the Platform, along with a rigorous user evaluation based on standardized usability criteria (e.g., drawn from [15], [36]). After its release, the Interactive Policy Platform is envisioned to help stakeholders to understand and support initiatives related to energy citizenship around Europe, ultimately contributing to the EU goal of a just and inclusive decarbonization pathway.

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