ENCLUDE
Energy Citizens for Inclusive Decarbonization

Development of decarbonization pathways based on social innovations of energy citizenship

WP5 – The impact of energy citizenship in decarbonization pathways

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Preface

The overall vision of ENCLUDE is to help the EU to fulfil its promise of a just and inclusive decarbonization pathway through sharing and co-creating new knowledge and practices that maximize the number and diversity of citizens who are willing and able to contribute to the energy transition. Motivated by achieving an equitable and sustainable future and the fulfilment of individual potential, ENCLUDE will contribute to the upcoming transformation of energy use by: (1) Assembling, aligning, and adapting disparate energy citizenship concepts for diverse communities of citizens and for different scales of policy making, lowering the barrier for action. (2) Operationalizing the energy citizenship concept at all scales of policy making for decarbonization. (3) Catalyzing a chain reaction of decarbonization actions across the EU.

1. Changes with respect to the DoA

The only deviation from the GA is the extension of D5.2 by 2 months (originally planned to be submitted by M18-November 2022, and now expected to be submitted by M20-January 2023). The due date was extended in order to incorporate insights of the case study data collection and meta-analysis into the development of quantifiable scenarios and decarbonization pathways under Task 5.2.

This deviation will impact neither the objectives nor the successful implementation of other Tasks and WPs. As a complementary action, under Task 5.2 we developed complementary narratives based on the concept of SSPs, which, as soon as the case study data collection process under WP3 was completed, we fitted to the case study specifications to derive quantifiable scenarios and case study tailored decarbonization pathways.

2. Dissemination and uptake

This report may easily be used both within and outside of the project, by researchers interested in the fields of energy system modeling and energy citizenship.

Hence, this report will be disseminated through the usual social media channels in order to communicate the key results and insights in an easily digestible manner. Also, it is envisaged that it will be uploaded to open research platforms (e.g., Zenodo), in order to reach a broader research audience.

3. Short Summary of results (<250 words)

This report is the second out of five deliverables under Work Package (WP) 5 of the ENCLUDE project and sets out to present the approach and, ultimately, the final decarbonization pathways developed for ENCLUDE based on the existing literature and the case study specifications that will take place under WP3. These pathways using as a starting point the insights from IPCC's SR1.5 to produce the most up-to-date and policy-relevant evidence on the contribution of energy citizenship in reaching climate neutrality, examine different states of uncertain parameters, to help understanding different forms of energy citizenship and specifically, the trends & patterns that were identified in the previous Task.

These pathways will then be used in the modelling exercises of the following tasks where the ENCLUDE ensemble of three well-established models, namely: an agent-based model (ATOM), a demand-side management model (DREEM), and an integrated assessment model (IMAGE), to emerging trends/ patterns of energy citizenship, will be employed.

4. Evidence of accomplishment

This report serves as evidence of accomplishment.

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Executive Summary

The process of decision making on climate and energy policy is a complex issue that is affected by an important number of internal and external factors that influence the dynamics of the energy system (such as technological advancement, societal change, behavioral aspects, economic development, and so on). Policymaking under deep uncertainty, particularly with its dependency on long-term estimations, implies that policymakers will face challenges when asked to design and implement new policies. Forecasting the future and determining the most likely evolution of its pathway has shown to be a challenging task, yet vital to assist in policy implementation.

As a result, it is critical to investigate and understand how a specific policy instrument affects various sectors. Modeling software capable of simulating multiple parameters, sectors, and contexts can aid in these investigations, allowing for the creation of multiple scenarios describing the shift to a carbon free energy system. As a result, it is an increasingly employed practice to employ model-based scenarios to examine potential environmental and energy-related trends influenced by uncertain dynamics.

With this goal in mind, within the activities of the ENCLUDE project and specifically in WP5, we have strived for the development of a comprehensive set of narratives and scenarios that will be used in the upcoming modeling exercises that will eventually produce outcomes related to the assessment of the decarbonization potential of energy citizenship. What is noteworthy to mention is that the narratives and scenarios developed are socially informed, meaning that they are formed, first and foremost, with the citizens' perspective in mind. One way of ensuring this is by supporting these narratives and scenarios on the real-life specifications of the case studies surveyed and analysed under WP3 activities. Moreover, the narratives will be intertwined also with the citizen clusters that are being developed under WP4 activities.

First, in order to reach our goal, we explored the literature around the development of decarbonization narratives and scenarios, where the Shared Socioeconomic Pathways (SSPs) are noteworthy. The SSPs present a set of five qualitative descriptions of future changes in demographics, human development, economy and lifestyle, policies and institutions, technology, and environment and natural resources. Based on the SSPs, we formulated three narratives that describe future systemic changes of the society and economy in general, thus providing us with future worlds that will be inhabited by citizens. The three world narratives are: **(i.)** *"A unified world"*, **(ii.)** *"A fragmented world"* and **(iii.)** *"A familiar world"*, which are operating on the spectrum of the nations' collaboration and unification versus their fragmentation.

In parallel, we brought the citizens to the forefront with the aim of building people-centric narratives, which will be the main driving narratives of the simulations later in the project. To develop these people-centric narratives, we started with the five (5) categories of emerging trends/ patterns around energy citizenship (i.e., **(i.)** the active participation in the energy market, **(ii.)** behavioral aspects of citizens, **(iii.)** individual lifestyle changes, **(iv.)** collective initiatives and expressions of energy citizenship, and **(v.)** political activities) that were previously identified in WP5. Based on these five categories, the people-centric narratives were developed to reflect these trends/ patterns. More specifically, the people-centric narratives were built upon four of the five categories of trends/patterns, with the exception of the *behavioral aspects of citizens*, as this category arguably permeates all citizens, regardless of other attributes and actions. Each of the other four categories play a dominant role in their respective narrative. The resulting people-centric narratives are listed below, with the corresponding category of trends/patterns in parentheses:

- Narrative 1: "Power to the People" (the active participation in the energy market).
- Narrative 2: "Band Together" (collective initiatives and expressions of energy citizenship).
- Narrative 3: "Habitual Creatures" (individual lifestyle changes).
- Narrative 4: "People to the Streets" (political activities).

- Narrative 5: “Business as usual” (current trends)

It is noteworthy to mention that the fifth narrative (“Business as usual”) forms the baseline narrative against which the decarbonization potential of the other four will be assessed. Finally, with the combination of world narratives and people-centric narratives we can formulate scenarios that can be modeled with the ENCLUDE modeling ensemble (ATOM, DREEM, IMAGE).

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List of Abbreviations/ Acronyms

CEI	Collective energy initiative
EC	European Commission
EU	European Union
GHG	Greenhouse gas
IAM	Integrated assessment model/ modeling
ICT	Information and communication technology
IPCC	Intergovernmental Panel on Climate Change
MS	Member State
RCP	Representative Concentration Pathway
RQ	Research Question
SSP	Shared Socioeconomic Pathway
WP	Work Package

1 Introduction

The Paris Agreement brought together all nations to join forces for the great cause of fighting climate change. The main goal is to deepen the global response to the climate change threat by holding the global warming well below 2°C above pre-industrial levels and to pursue efforts to limit it to 1.5 degrees Celsius this century(United Nations, 2015).

In order to limit global warming to this critical level, a great deal of worldwide effort and active involvement of regions, cities, businesses, and individuals along with commitments to the national levels is needed to achieve the decarbonization of the economy (Grubler et al., 2018). In this direction, the European Union (EU) as a frontrunner in global climate leadership, released the European "Green Deal" at the end of 2019, which is a comprehensive strategy for the EU to become the world's first climate-neutral continent by 2050 (European Commission, 2019). The "Green Deal" presented an initial roadmap of the key policies and measures needed to transform the EU's economy for a sustainable future. Apart from the overall goal of zero greenhouse-gas (GHG) emissions by 2050, the "Green Deal" set a new more ambitious target of GHG emissions reduction by at least 55% by 2030, compared to 1990 levels.

In addition, in 2020, a Recovery plan was also set by the European Commission (EC), the European Parliament, and EU leaders, to enable the EU countries to repair the economic and social damage caused by the COVID-19 crisis (European Commission, 2020).

Moreover, the 2022 Russia's invasion of Ukraine and the ensuing energy crisis in Europe brought about the issue of energy security of the common European energy system. Evoking the energy crises of the 1970s and late 2000s, when measures to enhance the liquidity of fossil fuel markets were perceived as the cure to these crises (Natorski & Herranz Surrallés, 2008), the current unprecedented situation calls for a different answer. The security of supply, widely understood under its geopolitical aspect, is now tightly correlated with the notion of affordability of energy, and therefore a more inclusive decarbonization strategy seems to be comprehended as the most viable long-term solution (Osička & Černoch, 2022).

To this end, the EC presented in March of 2022 the "REPowerEU" plan (European Commission, 2022)a joint European action to accelerate the clean energy transition and increase Europe's energy independence from unreliable suppliers and volatile fossil fuels. To achieve the goals, set out in the "REPowerEU" plan, actions on the following areas are outlined, as presented below:

- Energy savings
- Diversifying energy imports
- Substituting fossil fuels and accelerating Europe's clean energy transition
- Smart investment

Thus, even though the diversification of gas supply and short-term regression to the coal phase out plans of the Member States (MSs) are inevitable short-term measures, energy efficiency and renewable energy will be the main assets not only for mitigating climate change or moving to more sustainable lifestyles but also fundamental assets to assure national and European security (Osička & Černoch, 2022).

To move towards this direction even if the future is unclear, rapid action must be taken to put society on track for energy systems dominated by renewables by the middle of the century. This might take on a variety of forms, such as developing policies for the deployment of new generation assets, integrating various sector policies and balancing the interests of the many actors. Therefore, a shift from fossil fuels to renewables is planned and partially underway.

This shift can be seen, for example, in the share of primary energy from renewables that increases while coal usage decreases across pathways limiting warming to 1.5°C with no or limited overshoot. By 2050,

renewables (including bioenergy, hydro, wind, and solar, with direct equivalence method) would supply a share of 52–67% of primary energy in 1.5°C pathways with no or limited overshoot; while the share from coal decreases to 1–7%, with a large fraction of this coal use combined with carbon capture and storage (CCS) (IPCC, 2018). From 2020 to 2050 the primary energy supplied by oil declines in most pathways. Natural gas reduces by 13% to 62%, but some pathways show a marked increase albeit with widespread deployment of CCS (IPCC, 2018) . Our understanding of technological solutions is rich, however, how society and citizens will change, is less certain.

Behaviors and lifestyle are constantly changing and expected to change substantially in the future. Yet, anticipating or imagining how these will change is a challenge and generally unexplored in the context of climate change mitigation. A better understanding of social change is required to investigate potential futures.

1.1 Decarbonization pathways

Making decisions on climate and energy policy is a difficult process that is complicated due to a number of internal and external variables (such as technical advancement, societal change, behavioral aspects, economic development, etc.) that impact the dynamics of the energy system (Haasnoot et al., 2013). Decision-makers may experience confusion or incapacity while attempting to develop strong policies, frequently as a result of a lack of information regarding the uncertainties they must take into account (Forni et al., 2016). Policymaking under deep uncertainty, especially under long-term projections, implies policymakers will encounter difficulties when asked to design and implement a new policy. Predicting the future and deciding on the most probable evolution before applying a policy, has proven to be a difficult undertaking.

Scenarios offer a large flexibility to capture the full complexity of the system. In particular, qualitative scenarios can incorporate non-linearities, feedbacks, and surprises more easily than quantitative scenarios or models (Kok et al., 2006).

Therefore, researchers utilized the concepts of scenarios and pathways to present various future development trajectories without implying probabilities on the actual implementation of each scenario (Levesque et al., 2018). The aim of the adoption of long term global scenarios approach is to explore conditions leading to long term objectives (e.g., 1.5°C global warming) (O'Neill et al., 2017), while providing an outline of qualitative trends and quantitative projections regarding emissions, societal futures, and climate impacts including the evaluation of the implicit uncertainty of the scenarios. Long-term global scenarios have become of particular importance in climate change analysis and climate policy planning, since the publication of the Special Report on Emission Scenarios (Nakicenovic & Swart, 2000). The Shared Socioeconomic Pathways (SSPs) are the most recent global scenarios presenting a set of alternative futures of societal development till the end of the 21st century (O'Neill et al., 2017). Each of the five SSPs (presented in detail in **Section 3**) builds on a unique narrative and articulates the challenges on mitigation and adaptation to climate change that come along with each narrative. Despite their global-scale in their original form SSPs have been interpreted in quantitative scenarios in multiple studies (Bauer et al., 2017; Chakraborty et al., 2021; Dellink et al., 2017; KC & Lutz, 2017; Luo et al., 2020; Reimann et al., 2021), serving as the basis for long term projections concerning different contexts, sectors and scales to facilitate effective adaptation planning in the areas under study.

1.2 Decarbonization pathways and energy citizenship

Energy has been a crucial contributor on human development and prosperity accomplishments. Conversely, the energy sector is the main contributor to GHG emissions and air pollution (IEA, 2021), placing it at the epicenter of the global attempts of combating climate change. Energy transition to more resilient energy sources has been attributed as a key component of the global climate change mitigation and adaptation pathways.

Moreover, the Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways indicates that in a global scale, demand-side measures are key elements of 1.5°C pathways (IPCC, 2018). Lifestyle choices lowering energy demand and the land- and GHG-intensity of food consumption can further support achievement of 1.5°C pathways. Additionally, technological and social innovations and their uptake can contribute to limiting warming to 1.5°C, for example, by forming energy communities or by enabling the use of smart grids, energy storage technologies and general-purpose technologies, such as information and communication technology (ICT) that can be deployed to help reduce emissions (IPCC, 2018).

Europe as a frontrunner in meeting the Paris agreement "well below 2 degrees" targets has put in place a set of policies to foster the transition to a carbon neutral socio-economic environment. The need for a fair and inclusive energy transition and the advancing role of citizens in the future energy regime, are core aspects of the Europe's decarbonization strategy. Therefore, the concept of energy citizenship has emerged in the scientific literature. In D5.1 the identified energy citizenship trends and patterns are clustered in the following thematic groups:

- active participation in the energy market
- actions towards energy efficiency
- behavioral aspects
- collective expressions of energy citizenship
- political activities

Various energy sector challenges and the way they are addressed are crucial in shaping future transformation pathways with important implications for mitigation and adaptation. Five key energy sector challenges, to support basic human needs, development and well-being are (i) energy demand growth and its coupling with demographic and economic drivers, (ii) the phasing out of traditional forms of energy use, improving energy access and modernization of energy use in the context of structural economic change, (iii) the expansion of primary energy supplies, (iv) the future of existing and build-up of new energy infrastructures and technologies, and (v) the GHG and other pollutant emissions and their mitigation. These challenges are related to key scientific debates on global and long-term developments in the energy sector. The coupling between socio-economic development patterns and energy demand has been identified as a fundamental issue for understanding the scale and structure of energy demand (Csereklyei & Stern, 2015; Grubler et al., 2012; Jakob et al., 2012; Schäfer, 2005).

The complex decisions concerning mitigation portfolios for limiting warming to 1.5°C can have both a positive and negative impact on the achievement of other societal objectives, such as sustainable development. For example, demand-side and efficiency measures, and lifestyle choices that limit energy, resource, and GHG-intensive food demand support sustainable development. Limiting global warming to 1.5°C may be accomplished in tandem with poverty reduction and better energy security, and it can deliver significant public health benefits through improved air quality, averting millions of premature deaths. However, some mitigation strategies may result in trade-offs that must be considered, such as the land-use concerns in the case of bioenergy production (Vera et al., 2022). By examining prospective energy futures, alternative socio-technical routes, and scenarios, energy models can be used to advise and support policymaking processes in Europe.

As mentioned previously, the SSPs have been proposed as a new set of scenarios to be used as a basis of future climate research (O'Neill et al., 2014; van Vuuren et al., 2014). The SSPs form a set of five possible future development pathways that result in fundamentally different states of human society, when considering the capability to mitigate and/or adapt to climate change. The scenarios can be used in combination with additional, climate specific, policy assumptions to explore the effects, both positive and negative, of climate policies in different contexts or to assess the overall implications of climate change.

In order to take informed decisions, policy makers should be able to use supporting decision tools, which may explore the interplay of economic decision-making and behavioral heterogeneity in households' energy choices when testing common climate mitigation policies (e.g., carbon pricing) and socioeconomic pathways in a world with changing climate (e.g., SSPs).

SSP scenarios have been used to account for socioeconomic uncertainties associated with changes in the world's population, economic growth, technological development, urbanization, and education from 2020 through 2100, and also they have recently been used with an energy demand model formulated based on empirical equations to predict long-term useful energy and final energy demands in buildings (Chakraborty et al., 2021; Levesque et al., 2018).

1.3 Objectives and scope of this deliverable

This report is the second out of five deliverables under Work Package (WP) 5 of the ENCLUDE project and sets out to present the approach and, ultimately, the final decarbonization pathways developed for ENCLUDE based on the existing literature and the case study specifications that will take place under WP3. These pathways using as a starting point the insights from IPCC's SR1.5 to produce the most up-to-date and policy-relevant evidence on the contribution of energy citizenship in reaching climate neutrality, examine different states of uncertain parameters, to help understanding different forms of energy citizenship and specifically, the trends & patterns that were identified in the previous Task.

These pathways will then be used in the modelling exercises of the following tasks where the ENCLUDE ensemble of three well-established models, namely: an agent-based model (ATOM), a demand-side management model (DREEM), and an integrated assessment model (IMAGE), to emerging trends/ patterns of energy citizenship, will be employed.

As such, this report may easily be used both within and outside of the project, by researchers interested in the fields of energy system modeling and energy citizenship.

1.4 Structure of this deliverable

The remainder of this Deliverable is structured as follows:

- **Section 2** provides a short overview of the analytical approach followed to develop the decarbonization pathways based both in internal research and external input from other WPs.
- **Section 0** provides a short overview of the theoretical background on decarbonization scenarios and specifically the Shared Socioeconomic Pathways (SSPs). It also presents the way the SSPs will be integrated into the final set of decarbonization pathways.
- **Section 4** details the external input needed from other WPs, and most importantly the case study specifications that are derived from the WP3 survey.
- **Section 5** analyzes how the decarbonization pathways are developed, specifying the more technical aspects, such as the parameters that are used, the data collection and treatment process, etc. It also presents the final set of decarbonization pathways that will be modelled in ENCLUDE.
- **Section 6**, finally, provides conclusions, summarizes limitations, and indicates next steps and fields of future research.

2 Methodology

In order to develop the decarbonization pathways and scenarios for ENCLUDE the analytical approach that was employed comprised from two separate but interconnected processes: **(i.)** the desk research and review process around the field of the development of decarbonization pathways and scenarios, and **(ii.)** the case study specifications of WP3 derived from the external input of data and other relevant information from the activities performed in the other WPs of ENCLUDE. The above-mentioned overview is visually illustrated in **Figure 1**.

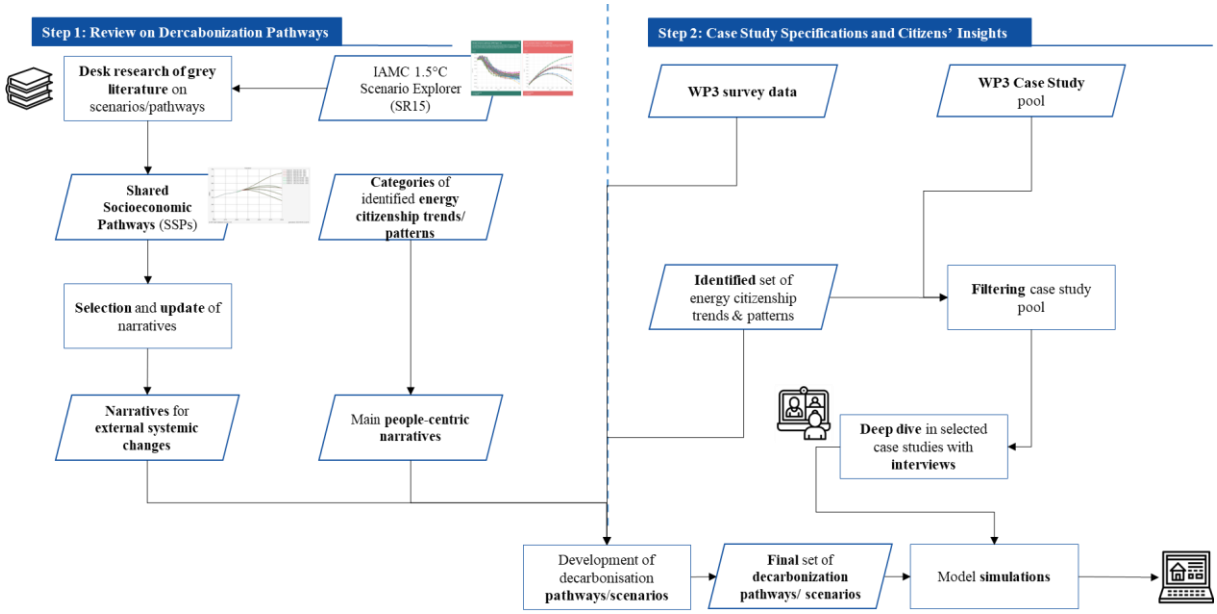

Figure 1. Analytical approach.

2.1 Step 1: Review on decarbonization pathways

For the WP5 research process, the starting point going forwards, was IPCC's SR1.5 (Intergovernmental Panel on Climate Change, 2019) and the accompanying database[1] (IPCC SR1.5 Scenario Explorer). Naturally, to ensure that the final set of decarbonization pathways developed for ENCLUDE are based on the most up-to-date and policy-relevant evidence on the contribution of energy citizenship in reaching climate neutrality we also used as a basis IPCC Special Report 6. Moreover, we expanded our research scope by performing desk research on the literature surrounding decarbonization pathways. Moreover, to deepen our understanding of decarbonization pathways in the context of modeling, we performed desk research on narrative formulation and decarbonization pathways. For this review the scientific research engines ScienceDirect and Google Scholar were used. The search term was defined as "{"pathways," "scenarios," "decarbonization," "(energy)citizen," "social aspects"} AND {"modeling," "energy modeling," "energy system modeling," "agent-based modeling," "demand-side management modeling," "integrated assessment modeling"}.

During this desk research in the scientific and grey literature, we identified the newly adopted framework of Shared Socioeconomic Pathways (SSPs) as best fitting for our purposes. This set of decarbonization pathways are part of a new framework that the climate change research community has adopted to facilitate the integrated analysis of future climate impacts, vulnerabilities, adaptation, and mitigation. The SSPs are based on five narratives describing alternative socio-economic developments, including sustainable development, regional rivalry, inequality, fossil-fueled development, and middle-of-the-

[1] https://data.ene.iiasa.ac.at/iamc-1.5c-explorer/#/login?redirect=%2Fworkspaces

road development, and are fitting to our work within ENCLUDE, since they encompass socioeconomic aspects in their development process.

Moreover, we selected some of the SSP narratives and we updated them, to the feasible extent, to also include real-world developments such as the current energy crisis influenced by the Russian invasion in Ukraine, thus formulating narratives for the external systemic changes that affect the citizens.

Continuing, based on the energy citizenship trends/patterns categories, we built people-centric narratives that reflect each category to describe futures where one category is prevalent amongst the others. This will lead us to a potential ranking of these categories based on the decarbonization potential each has to offer, among other co-benefits that can be produced. With the combination between the two set of narratives we can produce modeling scenarios.

Finally, the whole process of narrative development was also aided by a series of online discussions with our consortium, where all our partners provided insightful feedback on the overall structure of the framework and on what should be included and/ or emphasized regarding the produced co-benefits. The multitude of perspectives and variety of backgrounds of the consortium members enables us to incorporate aspects, previously not though of or disregarded, which in turn enriched the quality and content of the produced narratives.

2.2 Step 2: Case study specifications and citizens insights

As far as the external input necessary is concerned, the main source of information and data is, naturally, the case study pool developed and maintained in WP3. By using the case study pool of 78 collective energy initiatives (CEIs) collected by ENCLUDE partners as a basis, we were able to collect the data provided in the questionnaire developed by WP3. We then proceeded to filter the case study pool, in order to select the case studies that we would delve deeper into, based on the capabilities of the ENCLUDE modeling ensemble and the energy citizenship trends & patterns identified in D5.1 (Tsopelas et al., 2022).

In parallel, the questionnaire was examined to identify potential linkages between the questions and the accompanying data collected and the ENCLUDE modeling ensemble – i.e., specifying questions that will collect data, which in turn can be translated as input for the ENCLUDE modeling ensemble.

By combining the results of the separate internal and external processes, we were able to produce a final set of decarbonization pathways for ENCLUDE based on the most up-to-date and policy-relevant evidence on the contribution of energy citizenship in reaching climate neutrality and also the specifications of the case studies that are going to be modeled. With this set of decarbonization pathways, a series of modeling exercises will be conducted employing the ENCLUDE modeling ensemble, to assess the decarbonization potential of energy citizenship.

3 The Shared Socioeconomic Pathways

For more than two decades, long-term global scenarios have been critical in climate change analysis (Nakicenovic & Swart, 2000; Raskin et al., 2005; van Vuuren et al., 2012). While there are other methods for characterizing the future, such as the *assess-risk-of-policy* framework (Lempert et al., 2004; Webster et al., 2003), alternative scenarios are an important tool for exploring uncertainty in future conditions of the society and climate (Jones et al., 2014).

Societal development scenarios frequently include both qualitative and quantitative components (Ash et al., 2010; Raskin et al., 2005; Rothman et al., 2007; van Vuuren et al., 2012). Qualitative narratives (or storylines) describe the evolution of societal aspects that are difficult to quantify (such as the quality of institutions, political stability, environmental awareness, etc.), and provide a basis for further elaboration of the scenarios by users. Quantitative components define common assumptions for elements like population and economic growth, or rates of technological shifts that can be meaningfully quantified and used as inputs to models for modelling energy and land use, emissions, and other outcomes.

3.1 Goals of decarbonization pathways

Typically, decarbonization pathways are created to accomplish a single predetermined climate target. Reduced mitigation expenditures, rather than climate-related harm or long-term development impacts, are commonly used as the base for these paths to the desired climate target. Interactions between mitigation and other Sustainable Development Goals (SDGs), on the other hand, present both barriers and opportunities for climate policy. Consequently, substantial efforts are being undertaken to assess the effects of various mitigation pathways on long-term development, with a focus on aspects for which Integrated Assessment Models (IAMs) and other energy system models provide relevant information. More generally speaking, there are attempts to integrate climate change mitigation as one of multiple objectives that, broadly, better reflect societal concerns and may provide benefits at a lower cost than concurrent single-objective policies (e.g., (Clarke et al., 2014)). For example, carefully chosen policies can achieve universal energy access while simultaneously diminishing air pollution and mitigating climate change (International Energy Agency, 2017; McCollum et al., 2011; Riahi et al., 2012).

Gender, poverty, race/ethnicity, religion, age, or geographic location, social and economic inequities compound vulnerability to climate change and have created, and may continue to create, new vulnerabilities (IPCC, 2022). Climate change magnifies extant vulnerability and injustice, with the most marginalised communities suffering the most, including low-income women and children, indigenous or other minority groups, small-scale producers and fishing communities, and low-income countries. The most vulnerable regions and populations, such as those in East, Central, and West Africa, as well as South Asia, require the most adaptation. Climate justice initiatives explicitly address these multifaceted distributional issues as part of climate change adaptation, a seen recently by the agreement to provide *"loss and damage"* funding for vulnerable countries hit hard by climate disasters, with the issue being added to the official agenda and adopted for the first time at COP27[2]. Adaptation strategies, on the other hand, have the potential to exacerbate social inequalities, including gender, unless explicit efforts are made to change those imbalanced power dynamics, such as by creating spaces for inclusive decision making. Using local knowledge can aid in the resolution of issues such as climate change, food security, biodiversity conservation, and desertification and land degradation.

Communities, nations, and the world can pursue climate resilient development in a variety of ways. Moving forward necessitates confronting the complex synergies and trade-offs that exist between development paths, as well as the options, contested values, and interests that underpin climate mitigation and adaptation decisions.

[2] https://unfccc.int/news/cop27-reaches-breakthrough-agreement-on-new-loss-and-damage-fund-for-vulnerable-countries

3.2 Presentation of the Shared Socioeconomic Pathways

The climate change research community has been working to further develop a newer set of integrated scenarios describing future climate, societal, and environmental change, in the past years (Moss et al., 2010). This process began with the creation of Representative Concentration Pathways (RCPs), which describe a set of alternative trajectories for key greenhouse gas concentrations in the atmosphere (van Vuuren et al., 2011). Climate modelers used these to create a number of simulations of possible future climates for the twenty-first century (Taylor, 2009). In the meantime, other researchers are developing a new set of alternative future societal development pathways known as Shared Socioeconomic Pathways (SSPs).

The SSP narratives are a collection of five qualitative descriptions of future changes in demographics, human development, the economy and lifestyle, policies and institutions, technology, and the environment and natural resources. The conceptual framework for the design and use of SSPs calls for the creation of global pathways that describe the future evolution of key societal aspects. The following are the five narratives:

- **SSP1 Sustainability – Taking the Green Road:** The world is slowly but steadily shifting toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. The management of the global commons gradually improves, educational and health investments accelerate the demographic transition, and the emphasis shifts from economic growth to a broader emphasis on human well-being. Inequality is decreasing both across and within countries because of a growing commitment to achieving development goals. Consumption is geared toward low material growth as well as low resource and energy intensity.
- **SSP2 Middle of the Road:** The world follows a path in which social, economic, and technological trends do not deviate significantly from historical patterns. Development and income growth progress unevenly, with some countries making reasonably good progress while others do not meet expectations. Global and national institutions work toward, but make slow progress toward, achieving sustainable development goals. Environmental systems degrade, despite some improvements, and the intensity of resource and energy use decreases overall. Global population growth is moderate and will slow in the second half of the century. Income inequality persists or improves slowly, and hurdles to building resilience to societal and environmental changes persist.
- **SSP3 Regional Rivalry – A Rocky Road:** Reemergent nationalism, concerns about competitiveness and security, and regional conflicts all push countries to prioritize domestic or, at best, regional issues. Policies evolve over time to become more focused on national and regional security concerns. Countries prioritize energy and food security goals within their own regions over broader-based development. Education and technological development investments are declining. Economic growth is sluggish, consumption is materialistic, and inequalities persist or worsen over time. Population growth is low in developed countries and high in developing countries. Environmental degradation is exacerbated in some regions due to a low international priority for addressing environmental concerns.

- **SSP4 Inequality – A Road Divided:** High disparities in human capital investment, combined with growing disparities in economic opportunity and political power, lead to increased inequalities and stratification both across and within countries. The gap between an internationally connected society that contributes to knowledge- and capital-intensive sectors of the global economy and a fragmented collection of lower-income, poorly educated societies working in a labor-intensive, low-tech economy grows over time. Social cohesion deteriorates, and conflict and unrest become more common. The high-tech economy and sectors are experiencing rapid technological development. The global energy sector is diversifying, with investments in both carbon-intensive fuels such as coal and unconventional oil, as well as low-carbon energy sources. Local issues in middle and high income areas are the focus of environmental policies.
- **SSP5 Fossil-fueled Development – Taking the Highway:** This world increasingly believes that competitive markets, innovation, and participatory societies will produce rapid technological progress and human capital development as the path to sustainable development. Global markets are becoming more integrated. In addition, there are significant investments in health, education, and institutions to improve human and social capital. At the same time, the global push for economic and social development is being accompanied by the extraction of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles. All these factors contribute to rapid global economic growth, while global population peaks and declines in the twenty-first century. Local environmental issues, such as air pollution, are successfully managed. There is confidence in the ability to manage social and ecological systems effectively.

The SSPs provide a great range for building narratives that not only reflect today's world and its developments but also provide an outlook for the future changes that might occur. For example, SSP1 provides a positive outline of future changes toward a more sustainable path, emphasizing a more inclusive development that respects perceived environmental boundaries. To some extent, elements of this scenario can already be found in the proliferation of ''green growth'' and ''green economy'' strategies in industrialized and developing countries (UNEP, 2011; UNESCAP, 2012), although their efficacy has been questioned (Bina & La Camera, 2011). SSP5, in contrast, develops with fossil fuels, with a focus on competitive markets, technological innovation and participatory societies for progress, thus relying heavily on technoeconomic factors to describe future developments of the society and the world.

On the other hand, SSP2 sets a baseline scenario that provides the flexibility to assess the status quo projected into the future, with nothing shifting drastically. For example, emerging economies grow relatively quickly and then slow as incomes reach higher levels, the demographic transition occurs at average rates as societies develop, and technological progress continues without major slowdowns or accelerations. Thus, it is a dynamic pathway, yet one in which future changes in various elements of the narrative are consistent with middle of the road expectations, rather than falling near the upper or lower bounds of possible outcomes.

Moreover, SSP3 & 4 highlight not only the inequalities prevalent today in society, such as low and highly unequal investments in education, but also pinpoint to a narrative where the nations are more divided and are looking inwards their borders for energy security, an aspect that eerily reflects the last few months' developments, such as the Russian invasion in Ukraine and the rise of nationalistic parties to power in Member States e.g., Italy and Sweden. These SSPs, with their theme of international fragmentation and a world characterized by regional rivalry contrasts with globalization trends in other areas. Thus, the combination of impeded development and limited environmental concern results in poor progress toward sustainability.

4 Case Study Specifications and Citizens' Insights

To produce meaningful narratives and scenarios to assess the decarbonization potential of energy citizenship, it is necessary to utilize real-world data and insights. For this purpose, it is envisaged that the questionnaire as developed under WP3 and the accompanying data will be used to feed into the models, alongside the decarbonization narratives/ scenarios, with the aim of incorporating case study specifications into the modeling exercises. The collected data will be mainly utilized with the purpose of calibrating the ENCLUDE modeling ensemble, and specifically the ATOM and DREEM models, based on the survey conducted under WP3 activities. Below, the indicative questions and statements from the survey that are envisaged to be used for the ENCLUDE modeling ensemble, are presented

4.1 Questionnaire description and integration into the ENCLUDE narratives/scenarios

The questionnaire is developed for collecting qualitative and quantitative data, for example by using Likert scales and multiple-choice questions. These qe data, in general, will be used to calibrate the ENCLUDE modeling ensemble, to then perform the modeling exercises under WP5 activities, that eventually will quantifiably assess the decarbonization potential of energy citizenship, alongside other co-benefits such as self-sufficiency, energy justice, energy poverty alleviation, etc. In the subsections below, each section of the questionnaire, alongside the collected data, is described with respect to how it will potentially link to the ENCLUDE modeling ensemble. Moreover, in **Tables 1-8** the specific questions of each section of the questionnaire are presented.10

4.1.1 Socioeconomic Variables

Table 1. Indicative questions pertaining to socioeconomic variables.

Question
In which Country do you currently live?
How old are you?
Which of the following is your highest level of education?
How would you describe your household income in comparison with average households in your country?

Firstly, the questionnaire addresses the socioeconomic variables, such as age, gender, income level, education level, etc., that describe the population surveyed. This kind of data will enable to build basic profiles of agents in the ENCLUDE modeling ensemble that are representative of the general population of energy citizens.

4.1.2 Energy Poverty Variables

Table 2. Indicative questions pertaining to energy poverty variables.

Question
Have you ever had difficulties paying your bills for heating or electricity?
During the last winter/ summer, did you perceive your home as comfortable in terms of temperature?

Energy poverty and access to energy are increasingly important aspects of the energy transition; hence it is necessary to address these aspects within the ENCLUDE overall activities. Regarding energy poverty and energy access, the relevant questions and accompanying data will be integrated into the formation of decarbonization scenarios to produce results on the possible co-benefits of energy citizenship, apart from the decarbonization potential of the concept itself.

4.1.3 Political Orientation Variables

Table 3. Indicative questions pertaining to political orientation variables.

Question
How would you describe your political outlook with regard to **social issues** (e.g., family, religion, traditional values, etc.)? How would you describe your political outlook with regard to **economic issues** (e.g., taxes, cooperative vs. protective foreign economic policy, etc.)?

The questionnaire directly addresses the aspect of political orientation with respect to both *social* and *economic* issues **Table 3**. The insights gathered on the political orientation of the questionees will be integrated into the agents' profiles and will enrich and deepen the understanding of the citizens' behavior regarding decisions, such as the participation in a political movement around sustainable energy, while also exploring potential correlations between political orientation and aspects of the energy transition.

4.1.4 Material Culture Variables

Table 4. Indicative statements pertaining to material culture variables.

Statement
Heating with fossil fuels is a good energy solution. A reliable supply of electricity to private households can only be provided by companies. Investing in energy efficiency is beneficial for my household. Improving living conditions (e.g., thermal comfort) is as important for me as reducing energy consumption and bills.

In the Material Culture section of the questionnaire, the participants' views related to living conditions and material resources are explored. The insights and data collected from these questions will potentially feed into the households' consumption profiles regarding daily energy-related habits.

4.1.5 Climate Change Perception

Table 5. Indicative questions pertaining to climate change perception.

Question
Which do you think are the causes of the rising world temperature? Have you perceived changes in your local area that you think are connected to climate change?

By exploring the citizens' perception on climate change, we can build on the fundamental behavioral profiles of agents that form the basis and inform various decision-making processes.

4.1.6 Culture Orientation

Table 6. Indicative statements pertaining to culture orientation.

Statements	
I'd rather depend on myself than others.	Competition is the law of nature.
I rely on myself most of the time; I rarely rely on others.	If a co-worker would get a prize, I would feel proud.
I often do "my own thing."	The well-being of my co-workers is important to me.
It is important that I do my job better than others.	To me, pleasure is spending time with others.
Winning is everything.	

In the culture orientation section of the survey, the spectrum of individualism-collectivism is explored. The data gathered on the topic of this spectrum will feed into the agents' profiles that inform various decision-making processes, and can highlight deviations between the overall classification of the energy

citizenship trends/ patterns categories, i.e., individual level vs collective level.

4.1.7 Behaviour Change

Table 7. Indicative statements pertaining to behavior change.

Statement
My dwelling/home was upgraded (e.g., by retrofitting insulation or windows).
My heating system was significantly modernized.
What do you think was the main reason for the heating system modernization?
I changed my room temperature setting to a more comfortable level.
I don't know if anything was changed in my home during the last five years.
I changed my consumption behaviour by reducing the number of products/ services (for example clothing or electronic devices) purchased.
I changed my diet to less meat.
I changed my leisure activities from activities that need more infrastructure and equipment to activities that need less infrastructure and equipment (for example from motor sports to hiking).
I reduced the number of my holiday flights.

In this section of the questionnaire, data that are relevant to home upgrades and (consumption, dietary, leisure, transportation) behavior, can benefit both agents' behavior profiles and households' consumption profiles that will be modeled later on, and will enable better representation of various aspects of life.

4.1.8 CEI related Variables

Table 8. Indicative questions/ statements pertaining to CEI related variables.

Question/ Statement
First, think about the time when you started participating in the initiative. What were your main reasons to join (indicate a maximum of two): Which barriers do you see in your initiative? Please mark all options you feel are fitting for your initiative. How much do you agree with the following statement? "Only certain groups in society (e.g., middle-aged white males) engage in collective energy actions." • Since joining the initiative (or since I participated in its activities), I… [Strongly agree/ Agree/ Somewhat agree/ Neither agree nor disagree/ Somewhat disagree/ Disagree/ Strongly Disagree]
…contributed to my own health benefits (e.g., by reducing air pollution).
…strengthened my belonging to (link with) the community.
…increased my knowledge of how renewable energy technologies work and their potential benefits.
…gained practical skills in how to work with other people to bring change.
…took action to facilitate the low-carbon/green/clean energy transition in a field different to the initiative's activity area.
…have taken new pro-environmental actions and/or behaviors.
…reduced my energy bills.

…started to use less energy.

Finally, a large portion of the questionnaire is dedicated to exploring various aspects of Collective Energy Initiatives (CEIs), such as the reasons for joining a CEI, the diversity in CEIs, personal benefits, etc. This will enable the improvement of the ENCLUDE modeling ensemble regarding the collective expressions of energy citizenship, and specifically, the modeling of CEIs (e.g., energy communities & eco-villages, collective targeted actions, etc.).

4.2 Integration of case study specifications in the ENCLUDE narratives

In Table 9, below, the sections of the survey are mapped onto the energy citizenship trends/ patterns categories, with regards to how each survey section can feed into each category, based on the data collected from the survey answers.

Specifically, each section of the survey, with questions and data that it entails, can feed into the modeling exercises of each of the five (5) categories of energy citizenship trends/ patterns, and is denoted by an "**X**".

Table 9. Matching matrix of the questionnaire sections and the energy citizenship trends/ patterns categories.

Energy citizenship trends/ patterns category	Questionnaire Section							
	Socioeconomic Variables	Energy Poverty Variables	Political Orientation Variables	Material Culture Variables	Climate Change Perception	Culture Orientation	Behavior Change	CEI-related Variables
Active Participation in the Energy Market	**X**			**X**				
Collective Expressions of Energy Citizenship	**X**					**X**		**X**
Actions towards Energy Efficiency	**X**	**X**		**X**			**X**	
Political Activities	**X**		**X**					
Behavioral Aspects	**X**	**X**			**X**	**X**	**X**	

5 Scenarios formulation

The main approach for the conceptual design of the narratives is to focus on the citizens' perspectives, aiming for people-centric narratives. This approach relies on a process of matching the identified energy citizenship trends/ patterns to the narratives developed for ENCLUDE, while also utilizing the basic conceptual framework that underpins the SSPs. Meaning that starting from the SSPs as a basis, we build upon the insights developed within that framework and by adding our findings concerning energy citizenship we build the ENCLUDE narratives.
Moreover, based on the SSPs, we take into account the systemic changes that can potentially occur in future developments, regarding governmental institutions, organizations and nation-wide societal changes.

5.1 Systemic changes external to the citizens

By building on the SSPs presented earlier, we can formulate narratives regarding the external systemic factors that are related to institutions and organizations. For example, SSP1 provides a positive outline of future changes toward a more sustainable path, emphasizing a more inclusive development that respects perceived environmental boundaries. In contrast, SSP5 develops with fossil fuels for technological and innovation for development. A combination of SSP3 & SSP4 highlight not only the inequalities prevalent today in society, such as low and highly unequal investments in education, but also pinpoint to a narrative where the nations are more divided and are looking inwards their borders for energy security, an aspect quite reflective of today's real-world developments. Finally, SSP2 sits comfortably in between these two future societies, thus providing a baseline case for the development of current trends regarding institutional changes.
As a result, the three main narratives related to the external systemic changes that are formulated for ENCLUDE are presented below:

- **"A unified world":** In this possible future development of today's society, the changes concerning the institutions and organizations are focused on emphasizing the importance of citizens at the core of the energy transition, and the inclusive development that upholds the boundaries associated with the environment. There is a gradual shift from the sole focus of economic growth to an all-encompassing emphasis on human well-being. In general, consumption is aimed at achieving low material growth as well as low resource and energy intensity.
- **"A fragmented world":** In this potential future world, concerns about competitiveness and security, as well as regional conflicts, all push countries to prioritize domestic or, at best, regional issues. Over time, policies become more focused on both national and regional security issues. Countries prioritize energy and food security goals within their respective regions over broader development goals. Investing in education and technological development is decreasing. As a result, this theme of international fragmentation and a world marked by regional rivalry contrasts with other globalization trends. As a result of hampered development and limited environmental concern, progress toward sustainability is slow.
- **"A familiar world":** In this future development of the world with respect to external systemic changes, we are presented with minor deviations from past and present trends regarding institutions and organizations. This world is described by uneven evolution in areas such as income growth amongst the nations, with income disparities persistently present. Various institutions evolve slowly towards achieving sustainable development goals. There are advancements regarding environmental systems, but overall, they are characterized by degradation.

5.2 The ENCLUDE energy citizenship narratives

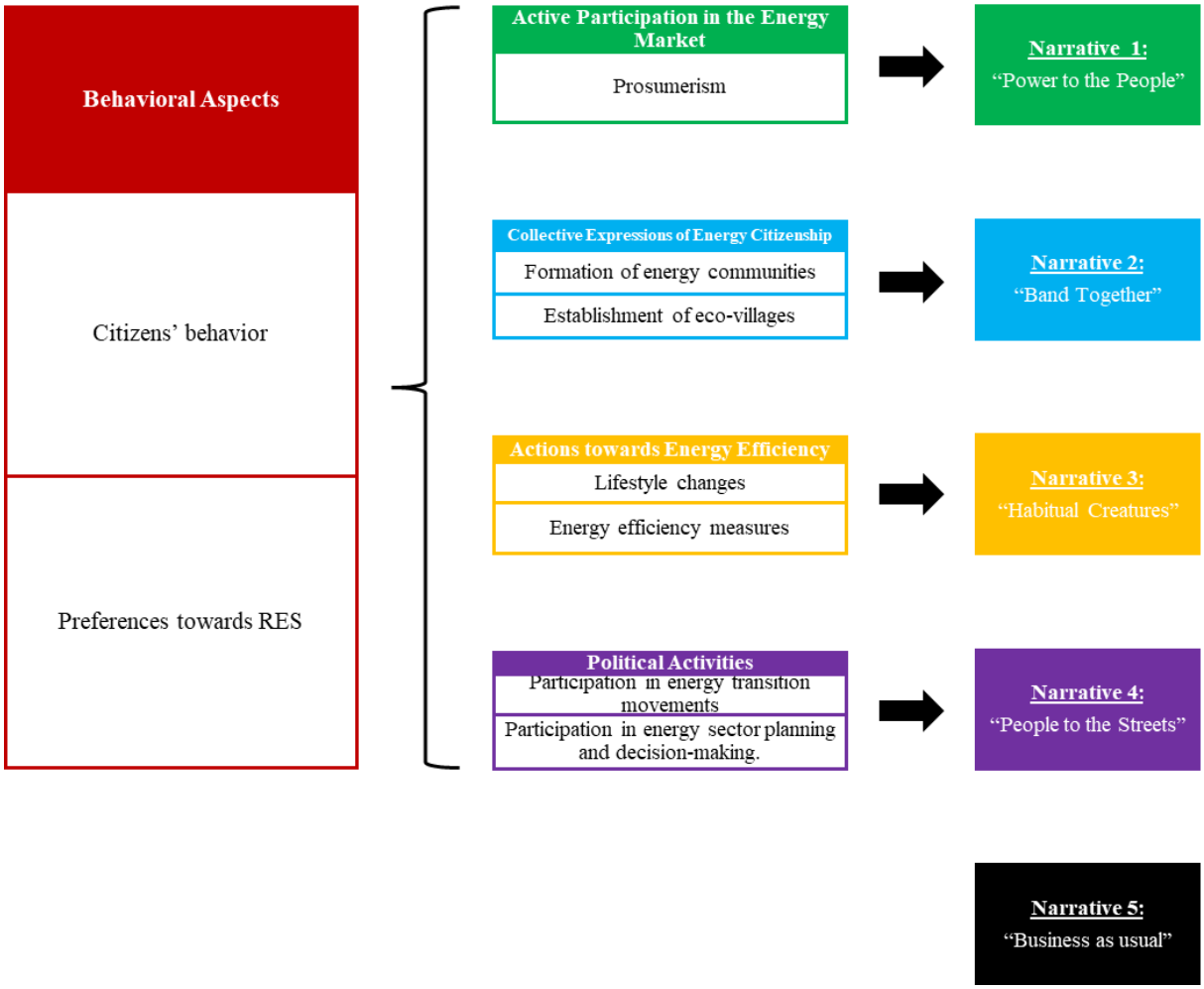

Figure 2. Mapping the energy citizenship trends/ patterns onto the ENCLUDE narratives.

Figure 2 shows the process of the people-centric narratives development based on the identified energy citizenship trends/ patterns categories. It should be highlighted that one of the energy citizenship categories, "Behavioral Aspects", does not correspond to a single narrative, but underpins all of the narratives. This is because the internal and abstract processes, that correspond to this category, permeate all of the citizens, irrespective of other categories included.

The ENCLUDE energy citizenship narratives, as they are formulated based on the identified energy citizenship trends/ patterns, are described below:

- Narrative 1 - **"Power to the People"**: This narrative builds upon the concept of an increasingly decentralized energy system e.g., with higher rates of prosumerism. Citizens are thought to increasingly becoming individual owners, thus, consuming their own electricity (Krumm et al., 2022), and playing a facilitating and supportive role in driving the energy transition (Trutnevyte et al., 2019). Within this narrative, various co-benefits can be explored such as the resulting percentage of the simulated population's access to energy and self-sufficiency.

- Narrative 2 - **"Band Together"**: A narrative focused on the concept of collectivistic actions of citizens in the energy system. Over the recent years, a rise in the formation of energy communities and other various collective energy initiatives (CEIs), such as energy collectives and co-operatives, that are legal entities that relate to the communal and localized production of energy, in order to optimize the usage of their resources (Moret & Pinson, 2019). These collectivistic actions are thought to be linked to terms such as energy justice, energy democracy, solidarity-based economy (Campos & Marín-González, 2020; Wahlund & Palm, 2022), and gender equality (Łapniewska, 2019), while also enhancing the overall sense of a strong community.
- Narrative 3 - **"Habitual Creatures"**: This narrative is focused more on the daily habits of citizens, and how little changes in everyday life can have an impact on the energy transition and on decarbonizing the energy system. The way our own norms, practices, and culture, such as various daily activities (e.g. home appliances' use, heating and washing, etc.) directly correlate to our energy behavior (Stephenson et al., 2010) and influence a household's levels of energy consumption. Individual energy conservation measures that result from the raised awareness around one's own energy consumption can be beneficial to the reduction of energy usage (Spyridaki et al., 2020).
- Narrative 4 - **"People to the Streets"**: A narrative focused more on the abstract concepts of political activism and movements surrounding energy and participation in social movements and civil society initiatives advancing democratic visions of energy transition (Wahlund & Palm, 2022). These processes enhance the active role of citizens by considering citizens' perspectives and giving them the opportunity to voice their opinions in matters that ultimate affect their own lives, thus exploring co-benefits such as energy justice and energy democracy, that are inherently abstract.
- Narrative 5 - **"Business as usual"**: A baseline narrative continuing trends and patterns identified today with minimal to no change in the current status quo. The world is moving in a direction where social, economic, and technological trends do not differ substantially from historical patterns. Development and income growth progress asymmetrically, with some countries making reasonable progress while others fall short. Global and national establishments work to achieve sustainable development goals, but progress is slow. The main utility of this narrative is to establish a reference point in order to assess not only the decarbonization potential, but also other co-benefits of energy citizenship.

5.3 Development of decarbonization scenarios

By combining the aforementioned narratives that describe both the external systemic factors at play, but more importantly the people-centric developments that empower the citizens to participate more actively in the energy transition we build the scenarios that will be modeled with the ENCLUDE modeling ensemble. This combinatorial framework is presented in **Table 10.** The whole process of narrative development was also aided by a series of online discussions with our consortium, where all our partners provided insightful feedback on the overall structure of the framework and on what should be included and/ or emphasized regarding the produced co-benefits. The multitude of perspectives and variety of backgrounds of the consortium members enables us to incorporate aspects, previously not though of or disregarded, which in turn enriched the quality and content of the produced narratives.

More specifically, in the first column of the table the main driving narratives that are related to the energy citizenship trends/ patterns are listed. In the following column ("*Energy citizenship trends/ patterns*") the respective category of energy citizenship trends/ patterns is presented. Moreover, in the column "*Systemic changes*" the three (potential eventualities that describe changes and shifts in institutions and organizations are presented for each of the main narratives. At this point is where the combination between the development of aspects related to citizens' activities and perspectives and the development of external changes becomes clear, thus providing us with a set of possible scenarios to explore future outcomes.

For each combination of the five (5) people-centric narratives and the world narratives, the fourth column ("*Clusters/ personas*") includes the make-up of the population modelled that will be the result of the activities performed under WP4. These clusters will describe types of citizens (*personas*) with characteristics regarding their behavior and consumption patterns.

Finally, in the last column ("*Results (decarbonization potential and co-benefits)*") the results of the modeling exercises will be presented. Primarily, the decarbonization potential of each main narrative will be produced by examining the potential decrease in GHG emissions when compared with the baseline narrative, thus providing an initial ranking of the narratives that could prove insightful to the potential policy- and decision-makers. Last but not least, various co-benefits of following a different path will be explored. The co-benefits that potentially can be produced are presented below (with the accompanying indicator in parenthesis), albeit not exhaustively:

- Inclusion/access (% of people with access to the grid)
- Self-sufficiency (% off-grid or feed-in tariffs)
- Energy justice (% low-income households with subsidies)
- Energy poverty alleviation (hours of load shedding)
- Energy health (pollution levels, calories burnt)

Table 10. Example of framework for the development of decarbonization scenarios based on the ENCLUDE energy citizenship narratives. For each combination of people-centric narratives (first column) and world narrative (third column) the mix of energy citizenship clusters *Cluster i*, i=1…N (produced from WP4 activities) with the accompanying percentages n_i% will be modeled.

Narratives	Energy citizenship trends/ patterns	Systemic changes	Clusters/ Personas		Results (decarbonization potential and co-benefits)
"Power to the People"	Active Participation in the Energy Market	A unified world	Cluster i, i=1…N	ni %, i=1…N	Produced outcomes and results primarily on the decarbonization potential of EC (% change w.r.t. the "Business as usual" narrative), and secondarily on other co-benefits [e.g., Inclusion/access (% of people with access to the grid), Self-sufficiency (% off-grid or feed-in tariffs), Energy justice (% low-income households with subsidies), Energy poverty alleviation (hours of loadshedding), Energy health (pollution levels, calories burnt)].
		A fragmented world	Cluster i, i=1…N	n_i %, i=1…N	
		A familiar world	Cluster i, i=1…N	n_i %, i=1…N	
"Band Together"	Collective Expressions of Energy Citizenship	A unified world	Cluster i, i=1…N	n_i %, i=1…N	
		A fragmented world	Cluster i, i=1…N	n_i %, i=1…N	
		A familiar world	Cluster i, i=1…N	n_i %, i=1…N	
"Habitual Creatures"	Actions towards Energy Efficiency	A unified world	Cluster i, i=1…N	n_i %, i=1…N	
		A fragmented world	Cluster i, i=1…N	n_i %, i=1…N	
		A familiar world	Cluster i, i=1…N	n_i %, i=1…N	
"People to the Streets"	Political Activities	A unified world	Cluster i, i=1…N	n_i %, i=1…N	
		A fragmented world	Cluster i, i=1…N	n_i %, i=1…N	
		A familiar world	Cluster i, i=1…N	n_i %, i=1…N	
"Business as usual"	-	A unified world	Cluster i, i=1…N	n_i %, i=1…N	
		A fragmented world	Cluster i, i=1…N	n_i %, i=1…N	
		A familiar world	Cluster i, i=1…N	n_i %, i=1…N	

5.4 Indicative Research Questions (RQs)

In this section we present the plan we aim to follow for each of the people-centric narratives by applying the framework presented earlier that includes both the people-centric and the world narratives on indicative case studies for the simulation with the ENCLUDE modeling ensemble. Below some indicative examples of the how we will approach the simulation of the various narratives, are presented for each of the five people-centric narratives. Finally, for each of the people-centric narratives research questions are formulated that will guide us through the modeling exercises that will follow in the upcoming months of WP5 activities.

Table 11. Indicative research questions and relevant case studies accompanying the people-centric narratives.

Narrative	Research question	Relevant case study
"Power to the People"	How can the diffusion of prosumerism under different sociopolitical contexts have an impact on the reduction of GHG emissions and other areas, such as energy access and energy security?	Schoonschip[3]
"Band Together"	How can the formation and diffusion of CEIs under different sociopolitical contexts have an impact on the reduction of GHG emissions and other areas, such as the citizens' health?	Attica Energy Community[4] CloughJordan eco-village[5]
"Habitual Creatures"	How the actions towards energy efficiency and various lifestyle changes under different sociopolitical contexts can have an impact on the reduction of GHG emissions and other areas, such as the citizens' health and energy poverty?	TRIME project[6]
"People to the Streets"	How can the diffusion and uptake of political movements related to the energy system under different sociopolitical contexts have an impact on the reduction of GHG emissions and other areas, such as energy justice and energy democracy?	Eko-svest movement[7]

5.4.1 "Power to the People" narrative

Under the *"Power to the People"* narrative the notion of the citizens' active participation in the energy market will be explored. Citizens are increasingly becoming individual owners, thus, consuming their own electricity (Krumm et al., 2022), and playing a facilitating and supportive role in driving the energy transition (Trutnevyte et al., 2019). "*Prosumerism*" is the concept that refers to the act of energy consumers to be also producers of energy, e.g., through small-scale RES technologies installed in their residence, etc., or to consumers being able to provide flexibility to the grid by adjusting their consumption patterns (Kühnbach et al., 2022).

This trend can have a quantifiable effect on the GHG emissions, while keeping intact the electricity grid (Stavrakas et al., 2020). By simulating the concept of prosumerism within different sociopolitical contexts (i.e., the world narratives) we can extract conclusions and insights about not only the decarbonization potential of prosumerism, but also about other benefits to the citizens, such as energy access and security.

This will be achieved through the employment of the ATOM model to assess the diffusion of prosumerism within a given population. The data extracted from the case studies, such as Schoonschip[3] with their sustainable floating neighborhood community that produces, stores and shares its self-produced

[3] https://schoonschipamsterdam.org

renewable electricity, operates its own grid and participates in the different electricity markets, and the questionnaire will enable us to better the capture the nuances of prosumerism.
The resulting RQ for this narrative that we will seek to answer with our modeling activities is:
RQ 1. How can the diffusion of prosumerism under different sociopolitical contexts have an impact on the reduction of GHG emissions and other areas, such as energy access and energy security?

5.4.2 "Band Together" narrative

With the *"Band Together"* narrative we seek to explore the effects of collectivism in the energy transition. *Energy communities* and other various *collective energy initiatives* (CEIs), such as energy collectives, co-operatives and eco-villages, are legal entities that relate to the communal and localized production of energy, in order to optimize the usage of their resources (Moret & Pinson, 2019). CEIs can bring numerous benefits at the local level, including new opportunities for local employment, improvements in social infrastructure developments, and environmental mitigation and enhancement (Nikas et al., 2020).
The establishment of *eco-villages* also expresses a collective form of energy citizenship, but they can present differences when compared to typical energy community structures. Eco-villages is a broad term that can encompass small, self-sufficient communities that focus on reducing their environmental impact and developing more sustainable lifestyles. Hence, eco-villages are often linked to more sustainable ways of living that can be found within the community, such as sustainable waste management systems, water treatment systems, irrigation, architecture, etc.
These collectivistic expressions of energy citizenship which form these types of communities can have a direct effect on the decarbonization of the energy system. This is not only achieved through communal production and consumption of energy, but also by developing more sustainable ways of living, thus producing in parallel health benefits for the citizens. Moreover, different *"worlds"* within which these CEIs can potentially exist can also affect the CEIs themselves, for example by enabling or hindering their formation and overall existence.
Within the ENCLUDE case study pool there is a plethora of energy communities to look for, such as the Attica Energy Community[4] which is a citizens' cooperative aiming at the collective production and consumption of clean energy and the implementation of green solutions in the city or the CloughJordan eco-village[5], which can be utilized alongside the data collected from the survey to simulate with the ENCLUDE modeling ensemble and quantify the aforementioned effects on both the energy system and the citizens themselves.
The resulting RQ for tis narrative that we will seek to answer with our modeling activities is:
RQ 2. How can the formation and diffusion of CEIs under different sociopolitical contexts have an impact on the reduction of GHG emissions and other areas, such as the citizens' health?

5.4.3 "Habitual Creatures" narrative

Within he "Habitual Creatures" narrative we aim to explore and evaluate the various effects the citizens' daily habits concerning their energy consumption. Various individual *lifestyle changes* that we as citizens can make, and can lead to more sustainable ways of living, are an important aspect of energy citizenship. The way our own norms, practices, and culture directly correlate to our energy behavior (Stephenson et al., 2010), the way we behave as consumers, and how our lifestyle affects climate change mitigation (Creutzig et al., 2018), have been areas of interest for many researchers. Various daily activities, such as home appliances' use, heating and washing, etc., influence a household's levels of energy

[4] https://www.facebook.com/atticaenergycommunity/
[5] https://www.thevillage.ie/

consumption and form a core part of being an energy citizen. Individual energy conservation measures that result from the raised awareness around one's own energy consumption can be beneficial to the reduction of energy usage (Spyridaki et al., 2020). For example, the action of lowering the thermostat of a residence can have a substantial impact on the energy use of the residence.

These actions towards energy efficiency can be directly linked with the reduction of GHG emissions and, in general, energy efficiency measures have been proven to be the most cost-efficient measures to tackle the energy crisis. In addition, there are other benefits that can be produced by these actions, such as the health improvement of the citizens and the alleviation of energy poverty, that plagues many citizens today.

Therefore, we envisage to explore and assess the quantifiable effect of these actions on the reduction of GHG emissions and other areas of interest, e.g., health benefits and energy poverty. By simulating with the DREEM model these individualistic actions under different systemic circumstances (i.e., the world narratives) we can extract useful insights on the decarbonization potential of this specific aspect of energy citizenship. In this endeavor, the data collected from the case study pool, where various collective targeted actions are included, will enable us to better simulate these types of actions. An example of such a case is the Energy Ambassadors of the TRIME project[6], who are trained social housing residents as Energy Ambassadors who then contact, advise and encourage their neighbors to adopt energy-saving behavior.

The resulting RQ for tis narrative that we will seek to answer with our modeling activities is:

RQ 3. How can the actions towards energy efficiency and various lifestyle changes under different sociopolitical contexts have an impact on the reduction of GHG emissions and other areas, such as the citizens' health and energy poverty?

5.4.4 "People to the Streets" narrative

Finally, under the "People to the Streets" narrative we will seek to explore the more abstract and indirect links between energy citizenship and decarbonization of the energy system. The *participation in energy transition movements*, such as social movements and civil society initiatives advancing democratic visions of energy transition, is another trend around energy citizenship (Wahlund & Palm, 2022), where citizens can have an active role in the dialogue around energy. One final aspect of energy citizenship that is identified is the *participatory processes* that take place in *energy sector planning* and *decision-making*, such as policy co-design initiatives, public consultation, and participatory energy landscape design (Wahlund & Palm, 2022).

Social movements, for example protests against fossil fuels can have considerable impact by holding accountable the responsible players in court cases. Moreover, by linking together various social movements to wider networks, creates more widespread collective actions that can potentially influence the general public opinion (Hielscher et al., 2022). These processes enhance the active role of citizens by considering citizens' perspectives and giving them the opportunity to voice their opinions in matters that ultimate affect their own lives; this is the reason why such processes should be emphasized. The effects not only on the reduction of GHG emissions but, arguably, more importantly on aspects of energy justice and energy democracy can potentially be assessed and quantified.

With the aim of connecting more abstract and qualitative aspects of energy citizenship to more concrete and quantitative outcomes of the energy transition, we plan to simulate political movements related to the energy transition and how their diffusion and uptake can have indirect effects on the decarbonization of the energy system and the strengthening of citizens' personal beliefs and norms regarding concepts such as energy justice and energy democracy. This is envisaged to be achieved through the simulation

[6] https://wayback.archive-it.org/12090/20210201145011/https://ec.europa.eu/energy/intelligent/projects/en/projects/trime

of case studies such as the Eko-svest[7] movement for changing national energy strategy and relevant legislation, in order to evaluate the changing of personal beliefs and norms can have lasting effects on the energy system.

The resulting RQ for tis narrative that we will seek to answer with our modeling activities is:

RQ 4. How can the diffusion and uptake of political movements related to the energy system under different sociopolitical contexts have an impact on the reduction of GHG emissions and other areas, such as energy justice and energy democracy?

[7] www.ekosvest.com.mk

6 Conclusions

The process of decision making on climate and energy policy is a difficult process that is complicated by several internal and external factors that influence the dynamics of the energy system (such as technological advancement, societal change, behavioral aspects, economic development, and so on).
Policymaking under deep uncertainty, particularly under long-term estimations, implies that policymakers will face challenges when asked to design and implement new policies. Forecasting the future and determining the most likely evolution before implementing a policy has been shown to be a challenging task.
As a result, it is critical to investigate how a specific policy instrument affects various sectors. When implementing a new policy, policymakers should keep this in mind. Modeling software capable of simulating multiple parameters, sectors, and contexts can aid in these investigations, allowing for the creation of multiple scenarios describing the shift to a carbon free energy system. As a result, it is common practice to employ model-based scenarios to examine potential environmental and energy-related trends influenced by uncertain dynamics.
With this goal in mind, within the activities of the ENCLUDE project and specifically in WP5, we have strived for the development of a comprehensive set of narratives and scenarios that will be used in the upcoming modeling exercises that will eventually produce outcomes related to the assessment of the decarbonization potential of energy citizenship. What is noteworthy to mention is that the narratives and scenarios developed are socially informed, meaning that they are formed, first and foremost, with the citizens' perspective in mind. One way of ensuring this is by basing these narratives and scenarios on the real-life specifications of the case studies surveyed and analysed under WP3 activities.
First of all, in order to reach our goal, we started exploring the literature around the development of decarbonization narratives and scenarios, and identified the SSPs as most relevant for the purposes of this task. The SSPs present a set of five qualitative descriptions of future changes in demographics, human development, economy and lifestyle, policies and institutions, technology, and environment and natural resources. Based on the SSPs, we formulated three narratives that describe future systemic changes of the society and economy in general, thus providing us with future worlds that will be inhabited by citizens. The three world narratives are: **(i.)** *"A unified world"*, **(ii.)** *"A fragmented world"* and **(iii.)** *"A familiar world"*, which are operating on the spectrum of the nations' collaboration and unification versus their fragmentation.
In parallel, we brought the citizens at the forefront with the aim of building people-centric narratives, which will be the main driving narratives of the simulations that will take place further in the project. To develop these people-centric narratives, we started with the five (5) categories of emerging trends/ patterns around energy citizenship (i.e., **(i.)** the active participation in the energy market, **(ii.)** behavioral aspects of citizens, **(iii.)** individual lifestyle changes, **(iv.)** collective initiatives and expressions of energy citizenship, and **(v.)** political activities) that were previously identified in WP5. Based on these five categories, the people-centric narratives were developed to reflect these trends/ patterns. More specifically, the people-centric narratives were built upon four of the five categories of trends/ patterns, with the exception being the *behavioral aspects of citizens*, as this category arguably permeates all citizens, regardless of other attributes and actions. Each of the other four categories play a dominant role in their respective narrative.
The resulting people-centric narratives are listed below, with the corresponding category of trends/ patterns in parentheses:

- Narrative 1: "Power to the People" (the active participation in the energy market).
- Narrative 2: "Band Together" (collective initiatives and expressions of energy citizenship).
- Narrative 3: "Habitual Creatures" (individual lifestyle changes).

- Narrative 4: “People to the Streets” (political activities).
- Narrative 5: “Business as usual”

It is noteworthy to mention that the fifth narrative (“Business as usual”) forms the baseline narrative against which the decarbonization potential of the other four will be assessed. Finally, with the combination of world narratives and people-centric narratives we are able to formulate scenarios that can be modeled with the ENCLUDE modeling ensemble (ATOM, DREEM, IMAGE).

6.1 Limitations

Going through the process of developing both the world narratives and people-centric narratives, we strived to create narratives that are grounded in scientific literature and bring added value to the space of decarbonization narratives/ scenarios. Nonetheless, in their current state, the narratives are the product of this internal process which, albeit robust, is somewhat incomplete, as it is important to bring also external feedback to the resulting narratives, in order to ground-truth them. With this goal in mind, we plan to bring citizens’ insights and feedback on the developed narratives to further enhance their robustness. This is envisaged to be achieved by engaging the participants of the ENCLUDE Academy, to express their views on both the world narratives and, more importantly, on the people-centric narratives. Moreover, the resulting narratives and scenarios, at this point, are presented in this deliverable in a more qualitative state. Meaning that they describe broader changes and developments in our future societies and economies. Nonetheless, the groundwork has been laid for the integration of the data that will be produced by the analysis of the case study questionnaire and it is envisaged that during the next phase of the WP5 activities, i.e., the preparation of and the implementation of the modeling exercises, the narratives and scenarios will take their final quantitative form.

6.2 Outlook: Preparing the ENCLUDE modeling ensemble

Moving forward with our WP5 activities, we begin to transition from this preparatory phase of, first, exploring the field of energy citizenship from a modeling standpoint, then adjusting our modeling ensemble and, finally, formulating narratives and scenarios that are going to be simulated, to the next phase of implementing these modeling exercises. With the sole focus of this deliverable being the development of the decarbonization narratives and scenarios, we next plan to incorporate the knowledge gained from the previous phase into the modeling exercises that will take place.

Specifically, the main task looking forward is to translate the collected data from the case study survey into inputs for the modeling ensemble. This process entails the exploration, first and foremost, of the raw data and then the insights gathered from the analysis performed from our colleagues in WP3 to extract and filter the useful information that will be used in our modeling activities. This process will be guided by the potential linkages outlined in **Section 4,** and of course by the narratives developed within this deliverable.

Finally, a series of data post-processing activities will ensure the implementation of the simulations required to achieve our overarching goal, which is to assess the decarbonization potential of the concept of energy citizenship. This will be further elaborated in upcoming deliverables D5.3 & D5.4.

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