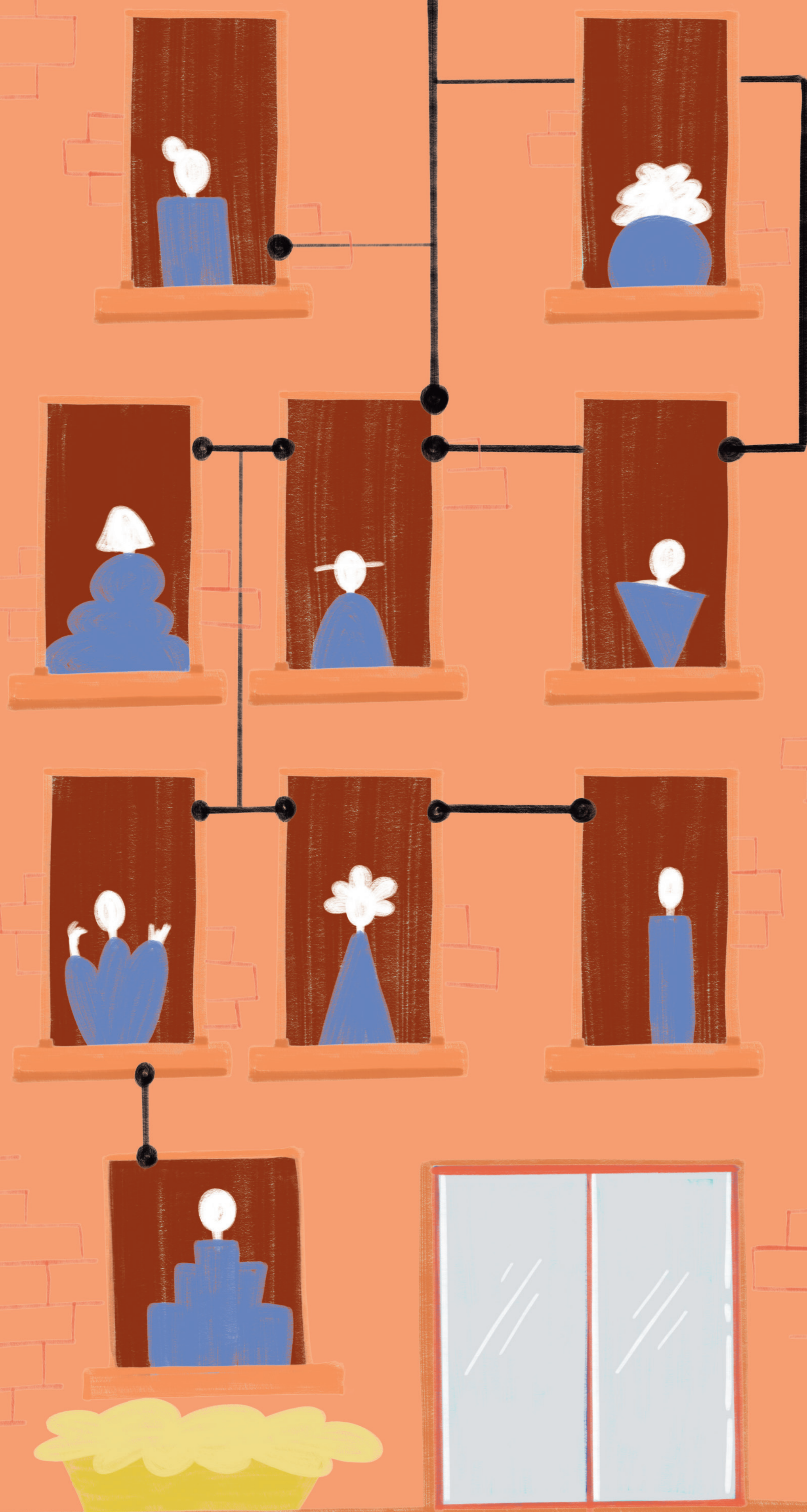
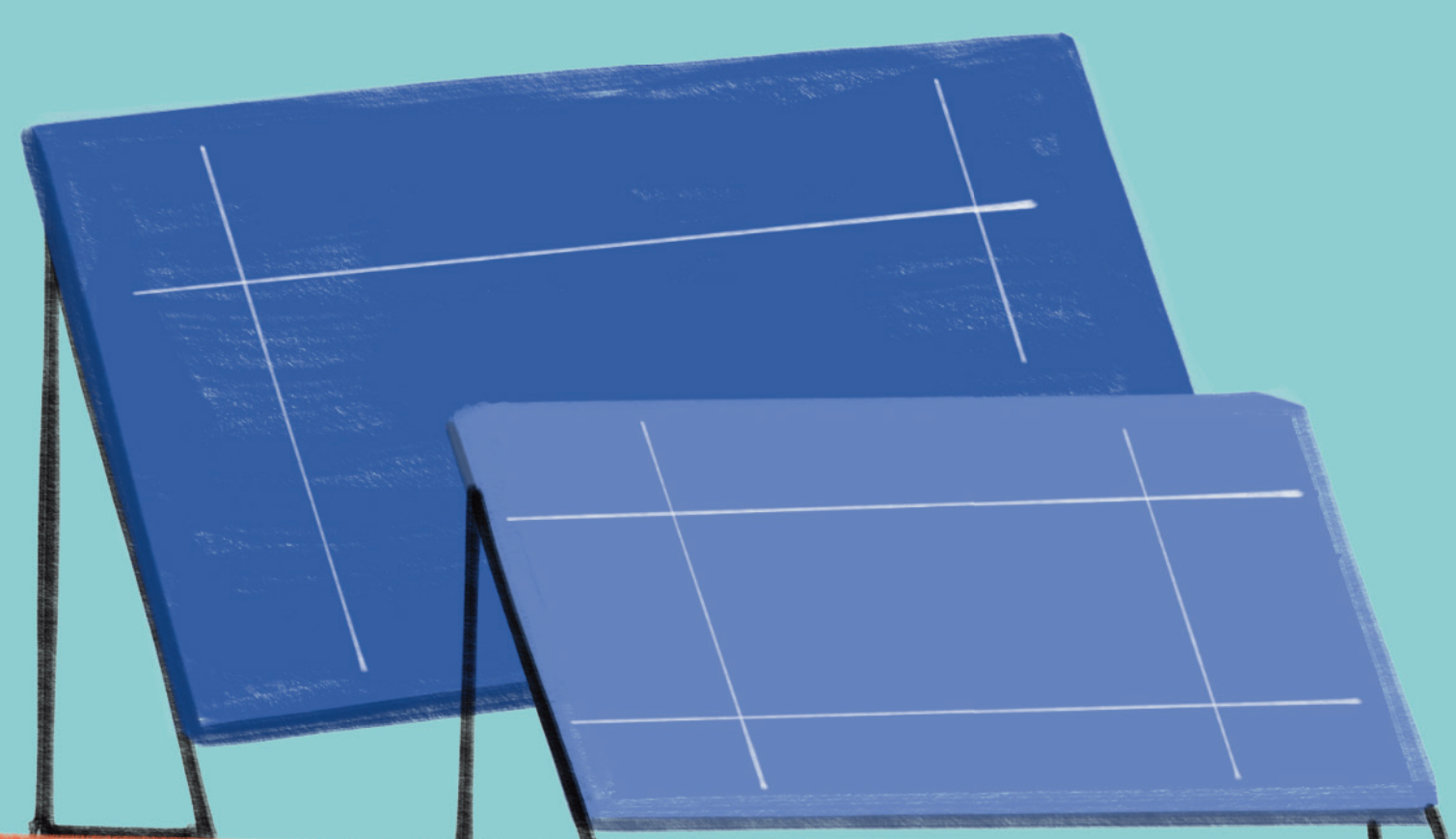


How to unite in

DIVERSITY

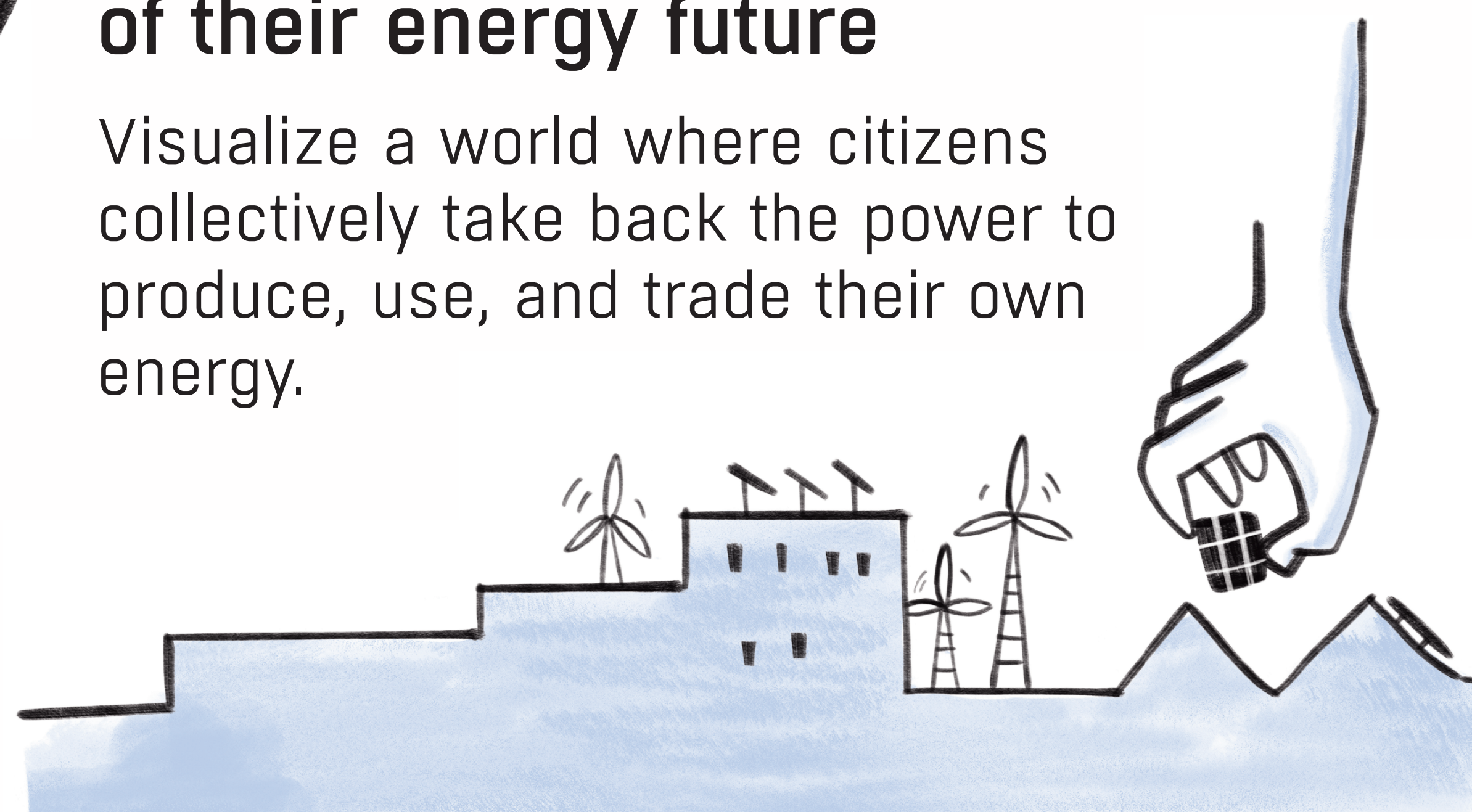
Collective Energy Initiatives
for a sustainable energy future



1

Empower Citizens and communities to take control of their energy future

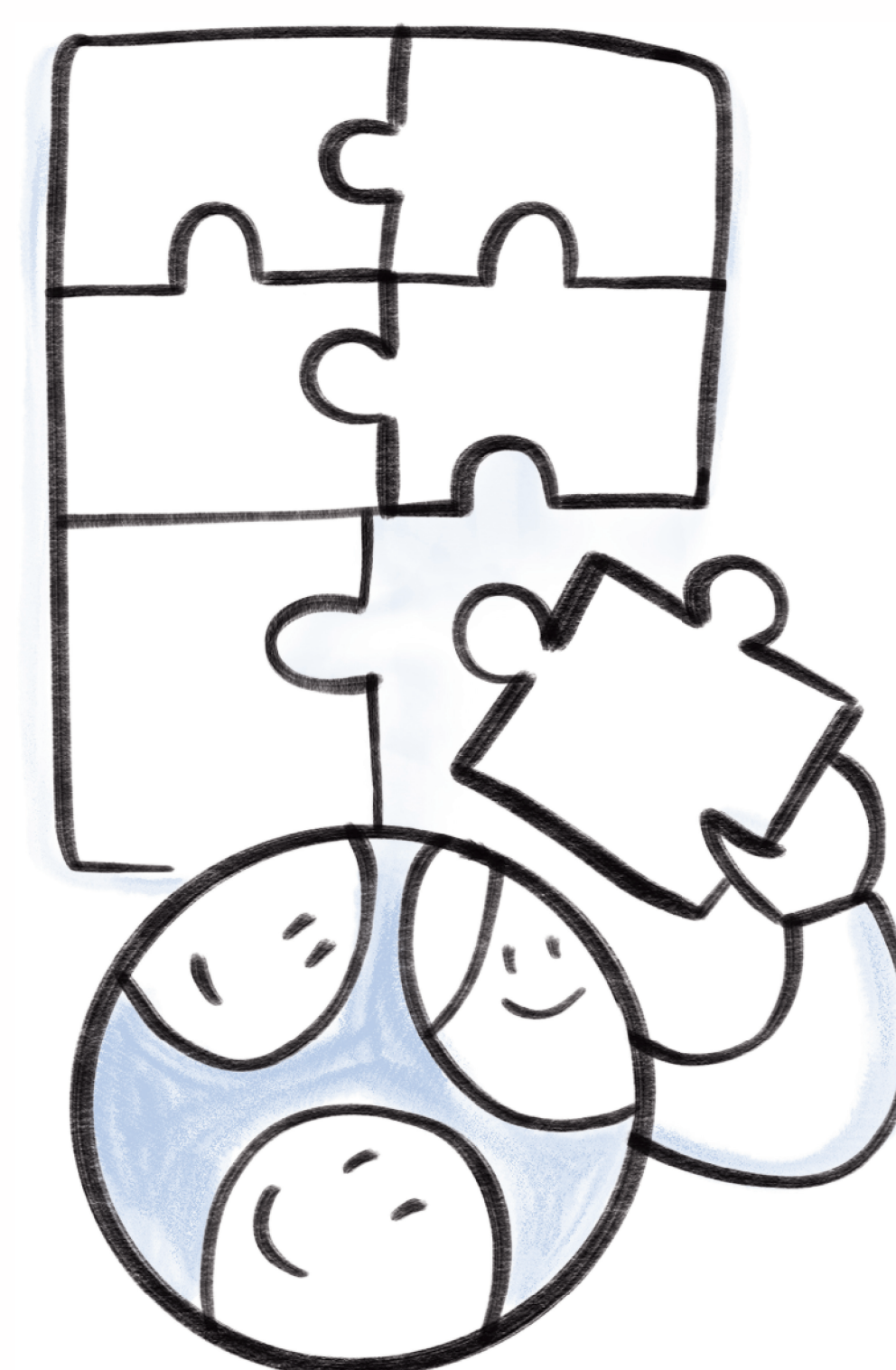
Visualize a world where citizens collectively take back the power to produce, use, and trade their own energy.



2

Recognize that there is no one-size-fits-all approach

Active Energy Citizens shape a diverse range of initiatives—each unique, just like the people they serve.



3

Acknowledge that we need an energy system that reflects Energy Citizens' choices, needs and values

Whether driven by sustainability, cost savings, independence, or innovation, every citizen can find a way to participate and make a difference.



4

Learn more about how we built a case-study pool of 68 unique and remarkable collective citizen initiatives and identified their needs, goals, and barriers

In order to gain insights into initiatives' leaders and members perspective read our **Deliverable on survey and case-study results**.

To do a deep-dive into specific key topics (among others energy poverty, motivations for joining, funding, regulations, community culture) read our **Deliverable on emergence and consolidation factors**.

Both can be found here:
encludeproject.eu/resources/deliverables



HYBRID FOREST ENHANCED WEATHERING (EW) AS A SERVICE IN UGANDA

Enabling Forest Owners to Increase the Carbon Drawdown of their Land with an “All-in-one Enhanced Weathering Service”

BY
Cornelius Chen-Chen & Sam Odong

Background

- **Definition** EW accelerates the natural weathering of minerals like basalt and olivine to sequester CO₂.
- **Reaction Mechanism:** CO₂ reacts with water to form carbonic acid, which dissolves these minerals, releasing calcium and magnesium. These elements form bicarbonates that flow to oceans, precipitating as carbonates, permanently trapping CO₂.
- **Key Minerals**
Basalt and Olivine: Selected for their reactive properties and natural abundance.

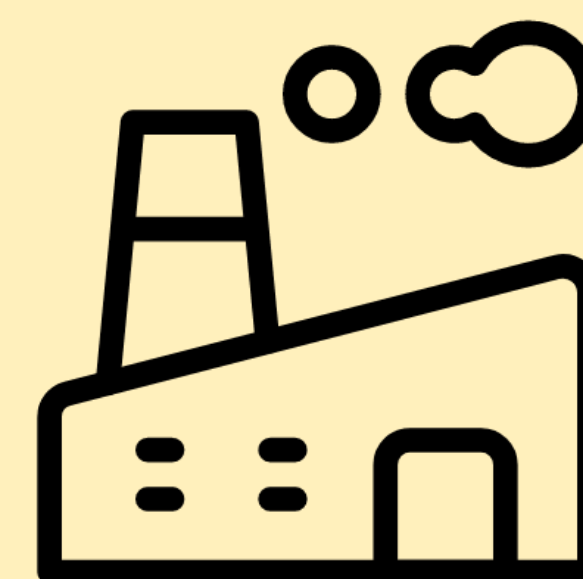
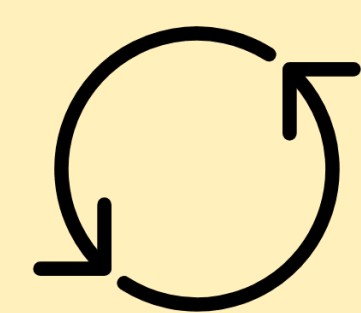
Problem

- **High Potential, Significant Barriers;**
 - *sourcing and processing minerals using clean energy*
 - *transporting and distributing these materials effectively*
 - *limited existing capacity for large-scale deployment.*
 - *establishing a reliable market where carbon credits can be sold efficiently.*

Who Has This Problem(Target Customer)

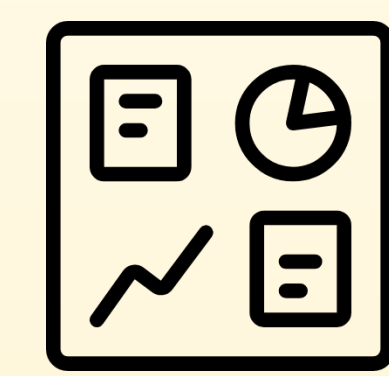


Forest Owners



Buyers of Carbon Credits

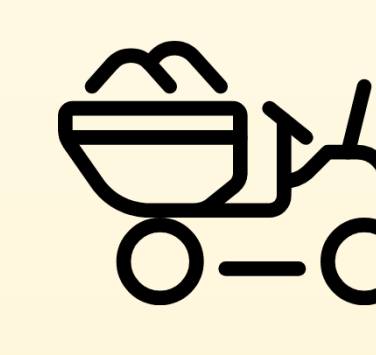
Solution



Enhanced
Weathering
Potential
Assessment



Methodology
& Registry

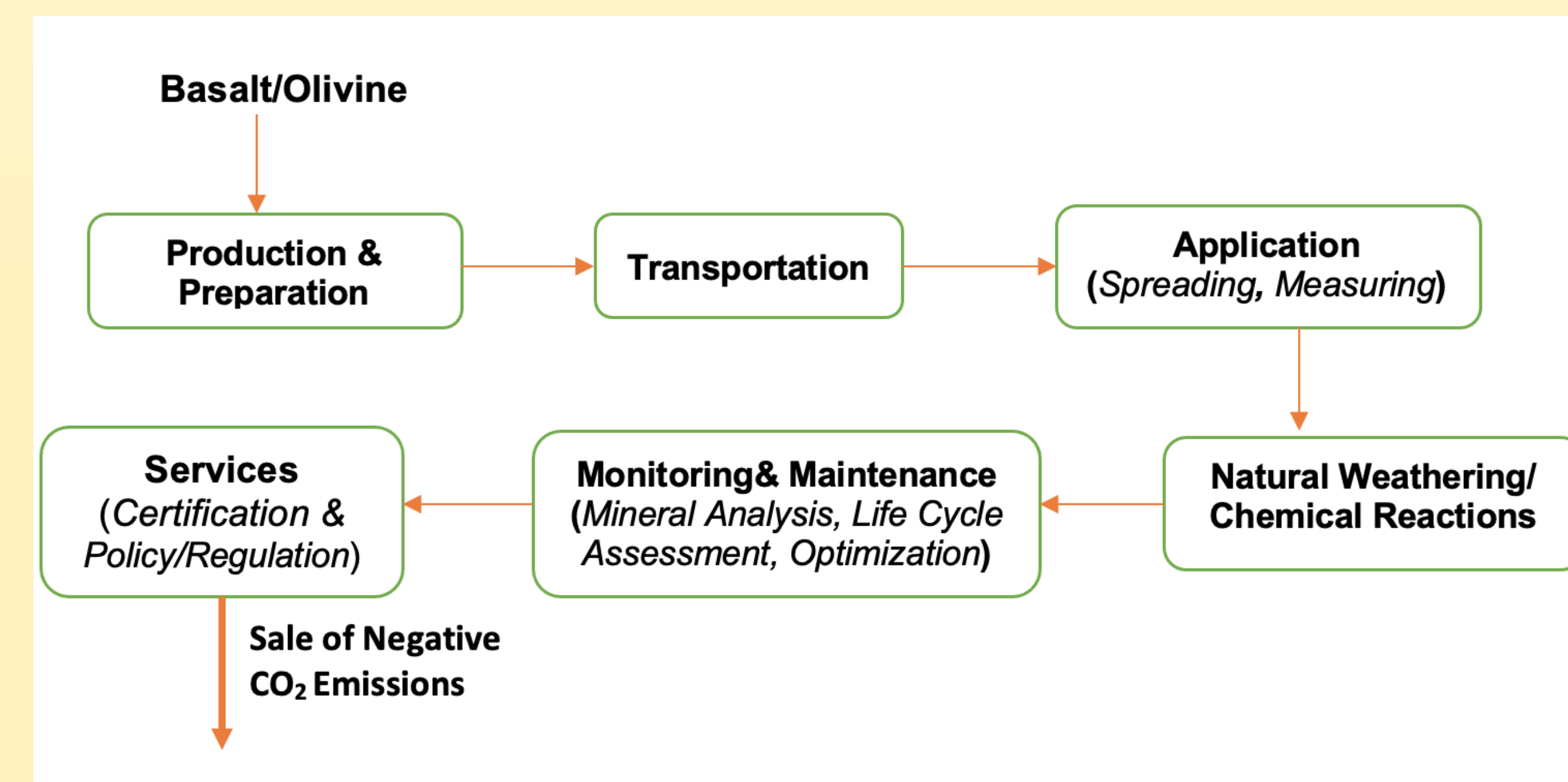


Logistics &
Operations



EW Credits
Marketplace

Process Flow



Impact

1 Million hectares of forest in East Africa (Uganda) (0.5%)

CO₂ capture per hectare: 4 tonnes

4,000,000 tonnes

- ❖ *SDG 2 (Zero hunger).*
- ❖ *SDG 12 (Responsible consumption & Production).*
- ❖ *SDG 13 (Climate action)*
- ❖ *SDG 14 (Life below water)*
- ❖ *SDG 15 (Life on land)*

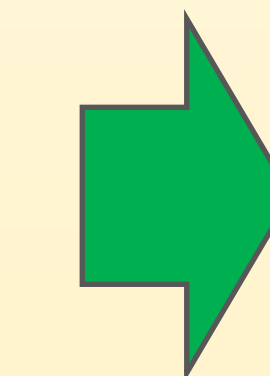
Vision

Our vision is to support forest and landowners to increase carbon credit generation potential with complementary technologies

Business Model

Sale of EW Futures

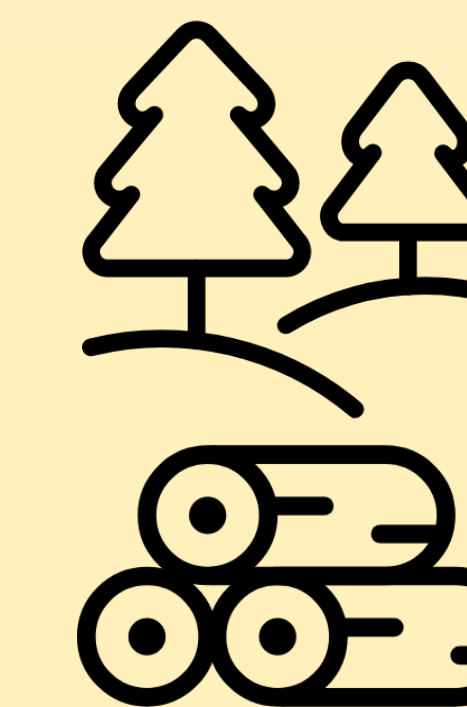
10% cut on EW futures
sold through marketplace



Sale of EW Futures & ex-Post Credits

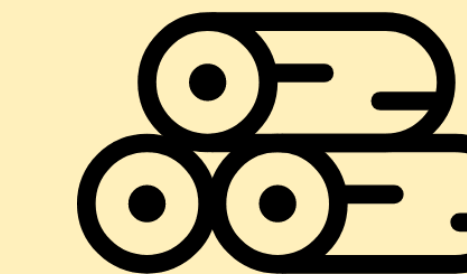
10% cut on EW futures + 5% on EW ex-
Post credits, sold through marketplace

USP



Forestry Credits

NCX, Pina.Earth



Biochar Credits

Puro.Earth, Carbonfuture



Enhanced Weathering Credits

No Services Yet

Forest Owners today have no access services allowing them to generate Enhanced Weathering credits

Energy Transition

- Supports energy transition by **offsetting emissions** from hard-to-decarbonize sectors (e.g., industry, transport).
- While renewables cut future emissions, EW actively **removes historical CO₂**.
- **Bridges the gap** toward net-zero emissions.
- Promotes **energy-efficient agriculture**, reducing the carbon footprint of food production.
- Generate **carbon credits**.



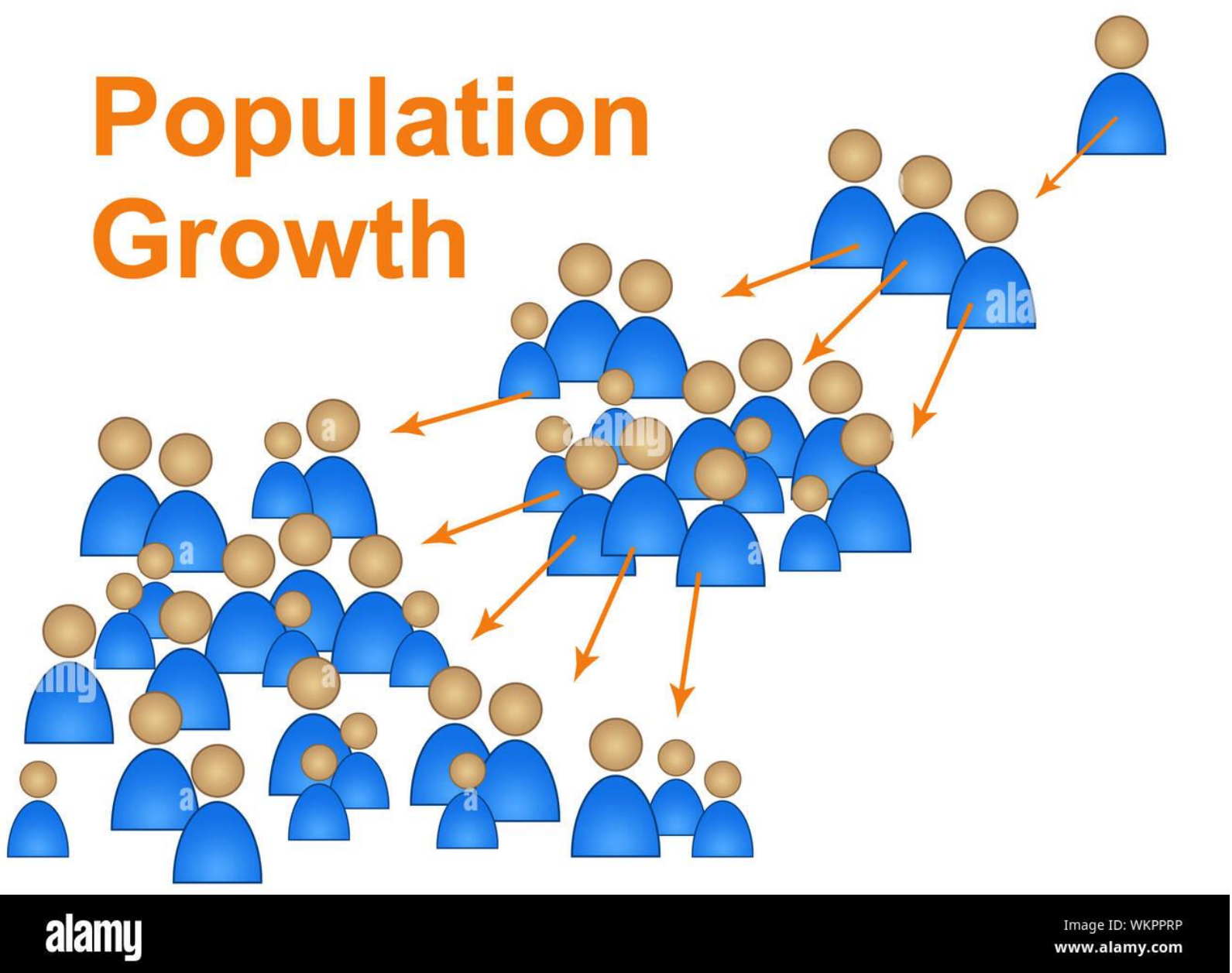
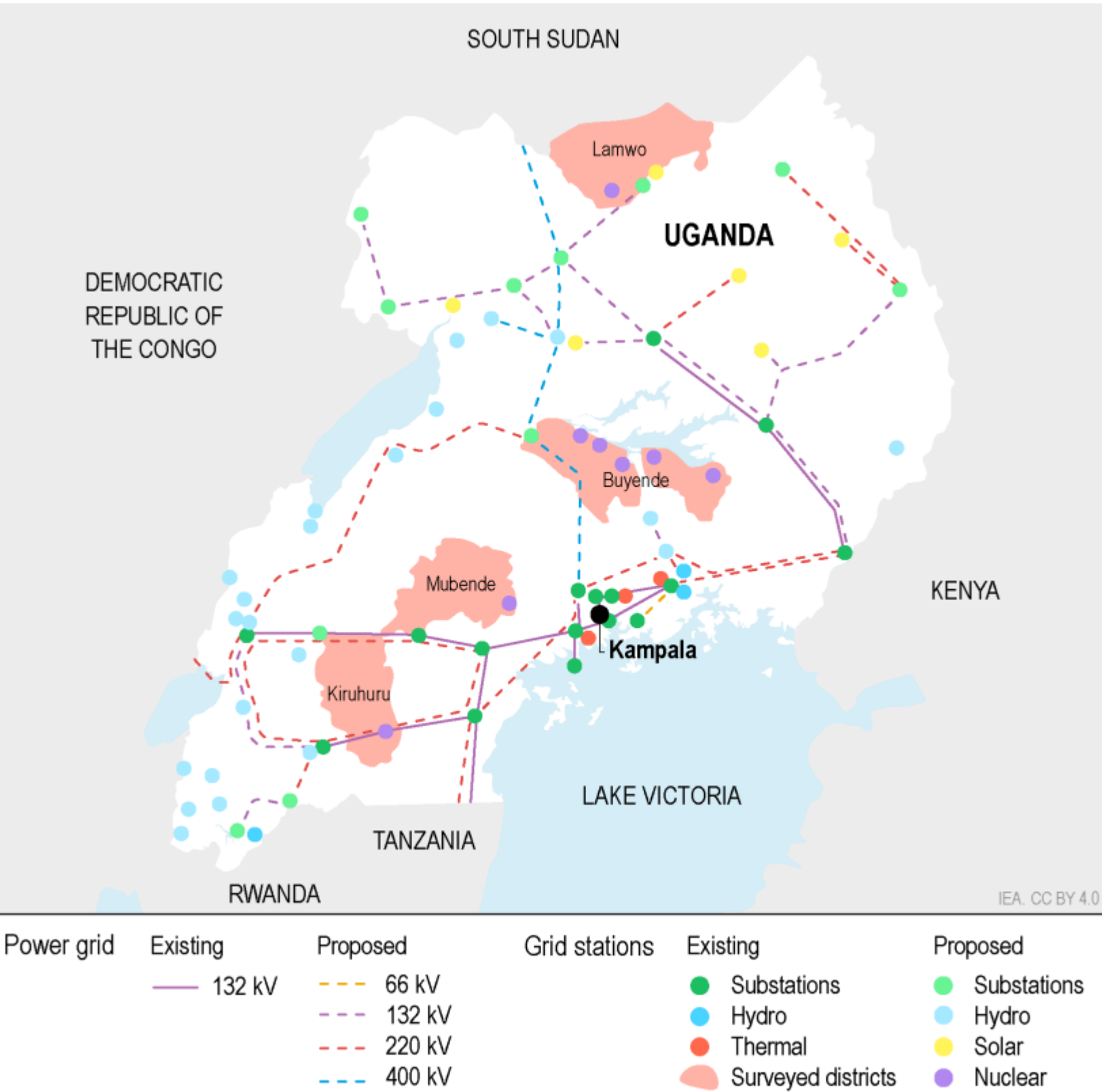
Contact; +256763843525

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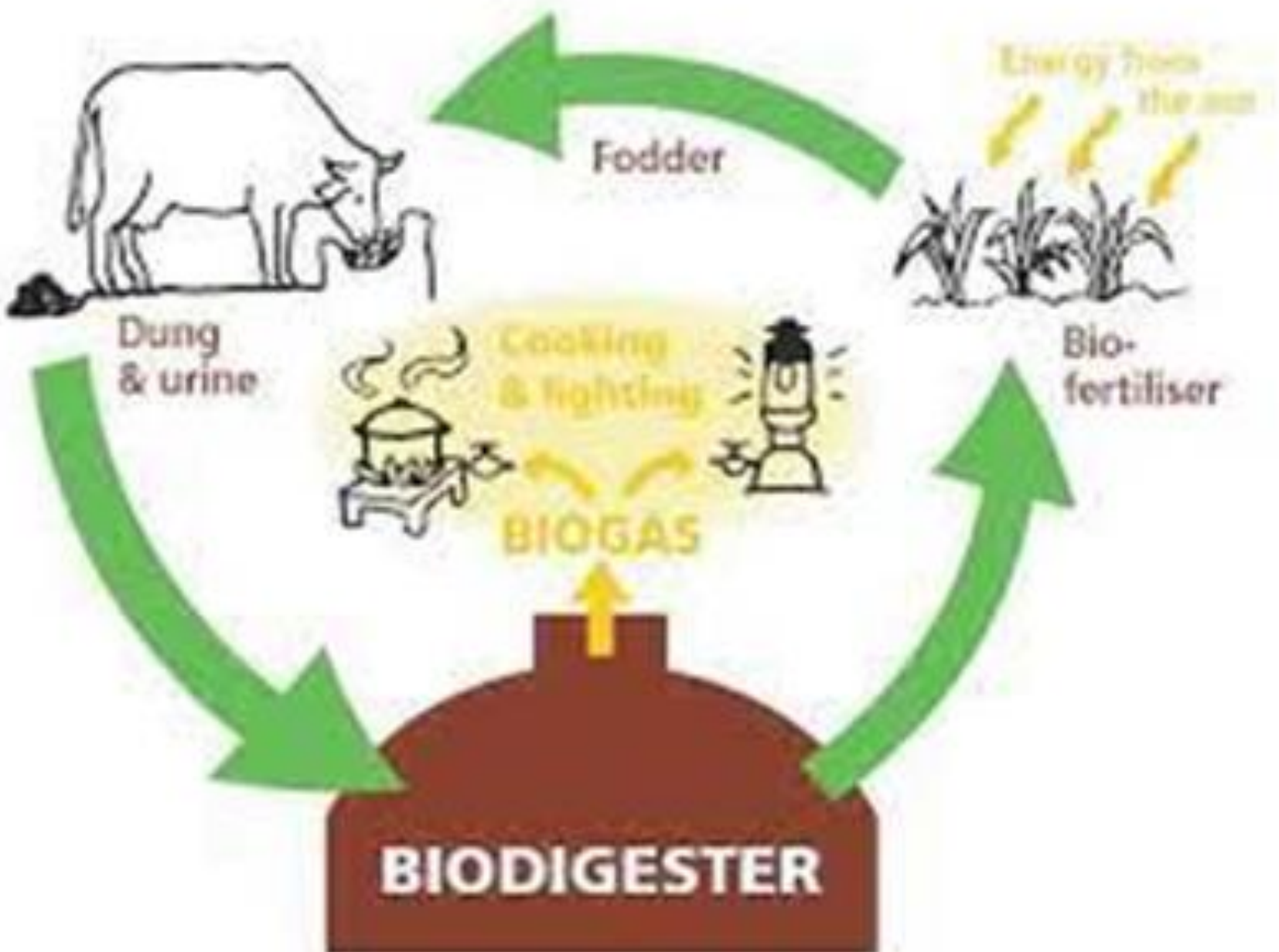
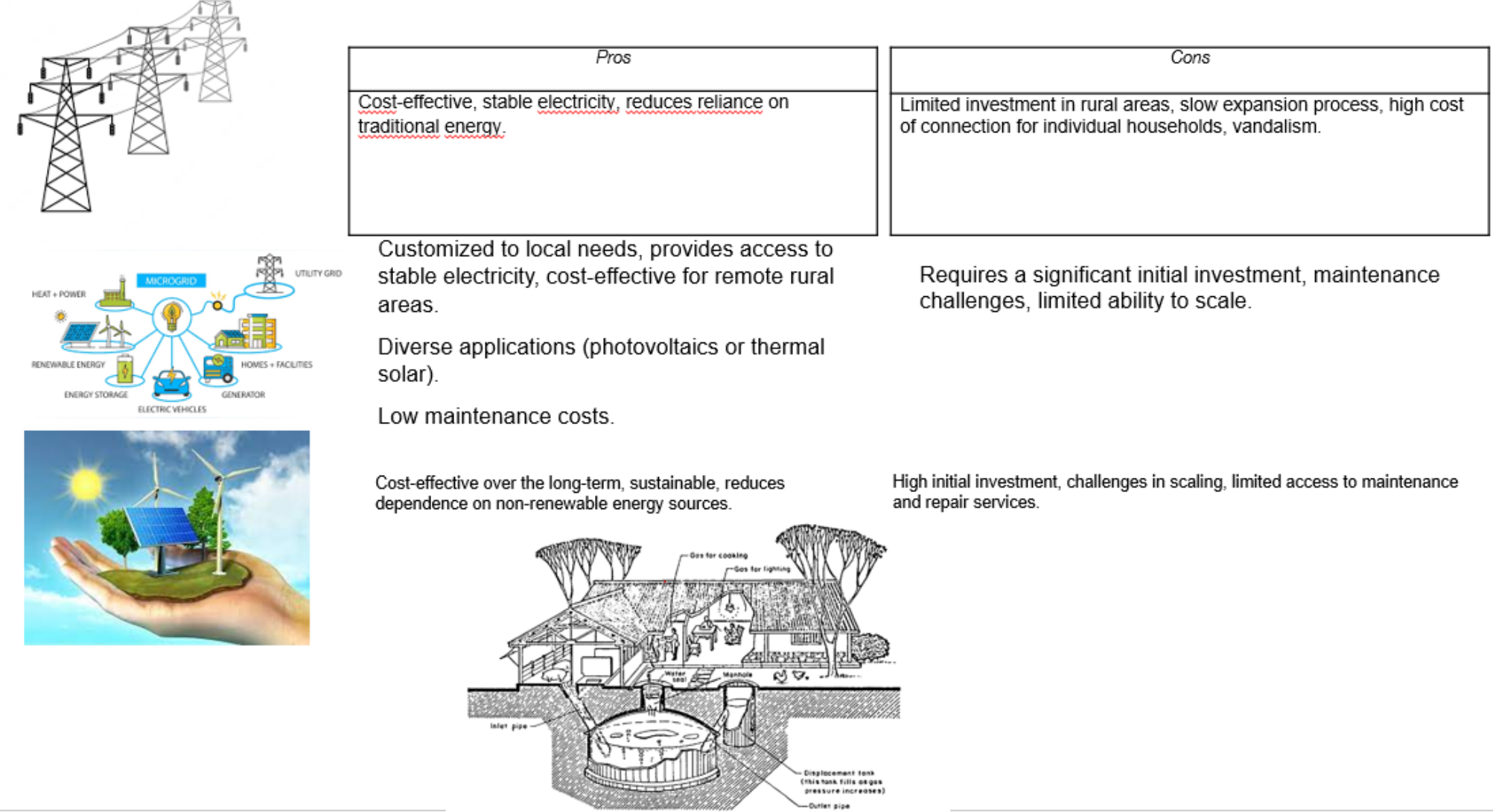


ENERGY CITIZENSHIP PROJECT.

DESIGN AND CONSTRUCTION OF MINI-BIOGAS PLANT FOR HOUSEHOLD USE.



Brainstorming solutions.



ACKNOWLEDGEMENT

I would also like to acknowledge with much appreciation the crucial role of the ENCLUDE ACADEMY for guiding me and quipping me with the necessary knowledge and materials that enabled me to successfully complete my project. A special thanks goes to Dr. BinBin for offering me an educative and financial support for my project.



ENCLUDE
Energy Citizens for Inclusive
Decarbonization



Horizon 2020
European Union Funding
for Research & Innovation



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Driving factors and citizen personas in support of the further diffusion and growth of Collective Energy Initiatives in Europe by 2030

Dimitris Fotopoulos, Vassilis Stavarakas, Nikos Kleanthis, Alexandros Flamos

Technoeconomics of Energy Systems laboratory (TEESlab), Department of Industrial Management and Technology, University of Piraeus, Karaoli & Dimitriou 80, Piraeus 18534, Greece.



Introduction

As Europe transitions to a sustainable energy system, achieving climate neutrality by 2050 hinges on the rise of collaborative **energy citizenship**. The ENCLUDE **"Band Together"** storyline highlights the collective actions that **energy citizens** are poised to undertake - such as forming energy communities, ecovillages, and other Collective Energy Initiatives (CEIs). These grassroots movements are driving localized green energy production and maximizing resource efficiency, with their numbers steadily growing in recent years.

To accelerate this progress, we analyzed and mapped out pathways for expanding CEIs, with the goal of better understanding and supporting their growth and influence. Our aim was to decode the mechanisms and motivations driving the establishment and spread of these innovative structures, helping them translate, replicate, and scale to a wider audience. To apply and test our approach, we selected **3 real-life CEIs** that differ in lifespan, population, and location:

- Cloughjordan Ecovillage in Ireland,
- EnergieC Midden-Delfland in The Netherlands,
- Belica Energy Community in North Macedonia.



Research questions

- Which are the **driving factors** supporting the diffusion and further growth of Collective Energy Initiatives in Europe by 2030?
- What is the **emission reduction (decarbonization) potential** related to the further growth of CEIs around Europe?

Methods

To model diffusion processes, the grAssroot iNnovation dIffusion MOdel (ANIMO) was employed. Designed and developed in the context of the ENCLUDE project, ANIMO delves into how envisaged social innovations are adopted by, and disseminated among, a network of individuals, with diverse socioeconomic, behavioral, and lifestyle profiles. In this work, the model is employed to simulate the further growth and diffusion of the 3 collective energy initiatives under study.

Factors driving participation in CEIs

By categorizing the questions in ENCLUDE's questionnaire for energy community members, we extracted **4 character attributes**, deemed crucial in the decision-making process of joining a CEI. By processing the survey data gathered by the ENCLUDE case study work on participants' income, lifestyle, education, etc., the character attributes were quantified and inserted as parameters into ANIMO for the 3 CEIs under study. **The identified character attributes are:**

Environmental Awareness: Captures individuals' knowledge and concern for environmental issues, often motivating them to participate in collective initiatives that address these challenges.

Energy Independence: Reflects individuals' desire for self-sufficiency and independence from the traditional power grid.

Sense of Community: Describes the feeling of belonging and connectedness, which strongly influences the willingness to engage in collective energy initiatives.

Financial Concern: Represents individuals' anxiety about their financial well-being, driving them to join collective energy initiatives for cost savings while also indicating their risk aversion.

Results

Personas

Based on these character attributes, we created **6 personas**, outlining profiles of citizens with **potential motivations** driving their **decision to join a CEI**.



The Green Guardian

Environmentalists prioritizing sustainability and energy independence. Concerned about traditional energy's impact, they seek to reduce their carbon footprint through on-site renewable energy and reduced grid reliance, aligning with their desire for energy autonomy.

The Security-Minded Sceptic

These individuals are mainly attracted to the financial benefits of an energy community. They value a strong sense of community and trust their neighbors' positive experiences, which can convince them of the financial advantages and encourage adoption.



The Eco-Collaborators

Community-oriented people that value collective action to address climate change. They are motivated by contributing to a larger environmental movement with like-minded neighbors and appreciate the focus on renewable energy to reduce their environmental impact.

The Tech Trailblazer

Excited about technologically innovative aspects of energy communities, they value smart home integration & increased energy independence. The environmental benefits are a bonus, but their primary interest is in experimenting with and adopting the latest tech.



The Self-Reliant Saver

These individuals seek self-sufficiency, valuing energy independence and financial savings. They aim to reduce reliance on the traditional grid, generate their own energy, and are motivated by lower energy bills and shared investment opportunities.

The Eco-Conscious Saver

Environmentally conscious and financially savvy, these individuals want to reduce their carbon footprint and save money or earn income by joining energy communities. Demonstrating cost savings and other financial benefits related to CEIs can influence their decision.



Projected growth

Findings revealed a strong correlation between **population density** and the projected growth of the CEIs under study. Densely populated areas seem to facilitate faster CEI expansion,

likely due to the enhanced **ripple effect** of the **"word-of-mouth" phenomenon**.

This is clearly demonstrated in the case of the "EnergieC Midden-Delfland" energy community, which resides in the most densely populated area.

However, **population density alone does not ensure growth!**

Another critical factor influencing expansion is the degree of interconnectedness within a society - what we term **social connectivity**. Essentially, tightly knit communities, whether solely due to population size or strong social bonds, enable quicker dissemination of information about the benefits of collectivism, driving higher growth rates. Strong relationships among community members are essential for fostering communication and cooperation. The "Band Together" storyline emphasizes the power of communal action, calling for unity and collective effort.



Conclusions

The results of this work reveal ways in which the presented approach can be useful in formulating policies to encourage the development or future growth of CEIs, as it can:

- ✓ **Identify and prioritize CEIs** with the **higher potential** and **optimize resource allocation**
- ✓ **Increase likelihood for citizen participation** Through optimized interventions, targeted engagement & communication strategies as well as tailored initiatives
- ✓ **Impact of CEIs on reducing CO₂ at the local level** Assist in motivating citizens and incentivizing investors
- ✓ **Optimized Infrastructure Development** Anticipating community expansion allows for informed and proactive infrastructure investment decisions, avoiding delays and bottlenecks that could impede the growth of energy communities and ecovillages.

Read our Deliverable for more information!

See results in the ENCLUDE interactive platform!

Images presented were created with the assistance of generative AI and DALL-E 2.

Citizen-led transitions towards justice and inclusivity: A “green” rebranding of a Coal and Carbon Intensive Region into a city of the people, by the people, for the people

Vassilis Stavrakas, Dimitris Papantonis, Alexandros Flamos

Technoeconomics of Energy Systems laboratory (TEESlab), Department of Industrial Management and Technology, University of Piraeus, Karaoli & Dimitriou 80, Piraeus 18534, Greece.



Introduction

The EU’s strategic vision and national policies offer a unique opportunity to transform **Coal and Carbon Intensive Regions (CCIRs)** in line with sustainable development goals. However, these regions, often facing job losses, aging populations, and environmental challenges, may resist change. Successful transformation hinges on addressing structural, cultural, and perceptual barriers to foster local collaboration and achieve early justice gains, sparking broader positive impacts. A notable example is the municipality of **Megalopolis in Greece**. Originally rural, Megalopolis became a lignite mining hub in the 1970s, hosting 5 different lignite power plants over the years, which have been providing the local community with several job opportunities and have been fostering local economy. The 2019 Greek National Energy and Climate Plan mandated phasing out lignite power plants by 2023, a very ambitious goal, which due to the extreme events of the past few years, led to a **new dependence on natural gas**. This transition risks long-term fossil fuel reliance, leading to higher energy costs, potential gas shortages, and delayed adoption of green energy solutions.



Over the past few years, local stakeholders have suggested a post-lignite trajectory for Megalopolis that includes renewable energy, eco-tourism, alternative agriculture, and infrastructure improvements. Key steps include establishing a secure legal framework for renewable energy investments and energy efficiency upgrades. Proposals also include forming energy communities and offering tax exemptions to attract investments in clean energy projects. *However, the plan's success heavily relies on citizens' willingness to invest in new technologies, highlighting the need for innovative business models and legal frameworks to demonstrate economic and environmental benefits.* Given the growing involvement of citizens and other actors in combating the climate crisis and transforming the energy system, this case study explores *if a citizen-led energy transition in Megalopolis could lead to a “green” rebranding into a city of the people, by the people, for the people.*

Research questions

- ✓ Can a **citizen-led transition** based on energy efficiency investments and lifestyle & behavioral changes **support a just & inclusive transition** in the Coal and Carbon Intensive Region of Megalopolis?
- ✓ What is the **post-lignite development trajectory** & the **potential benefits** of a **people-powered transition** that does not rely on traditional fossil fuels?
- ✓ What is the **emission reduction (decarbonization) potential** of different transition pathways at the municipality level?

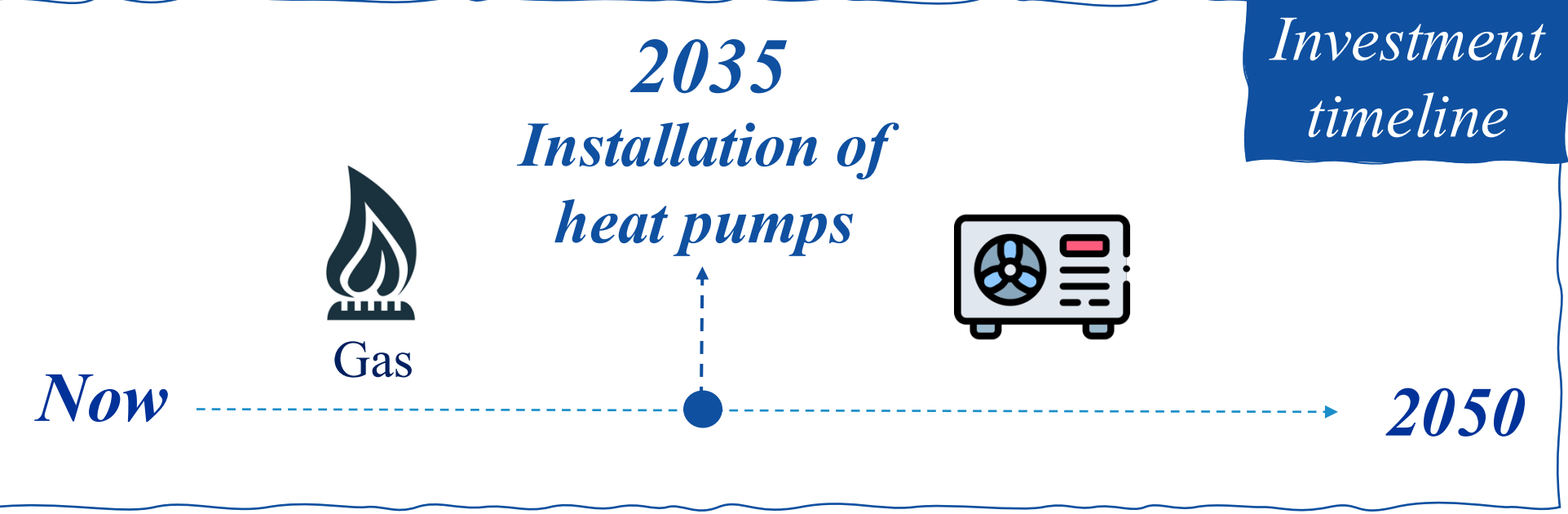
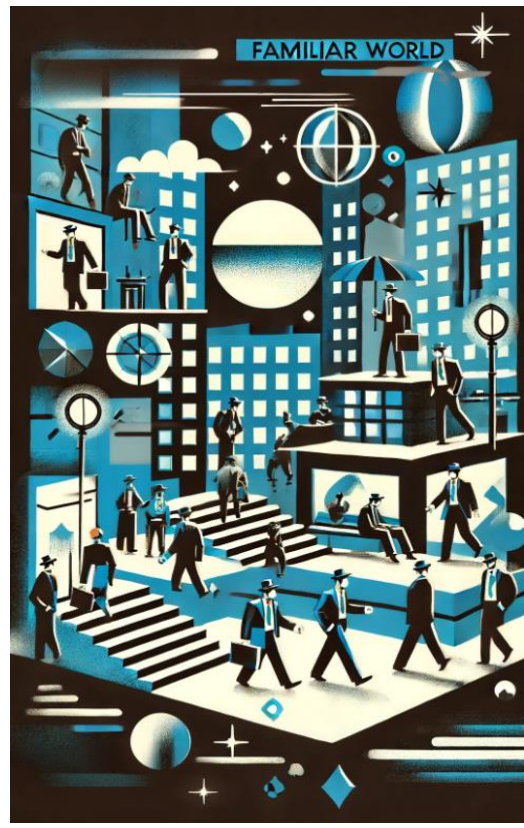
Methods

Using the **Dynamic high-Resolution dEmand-side Management (DREEM)** model, we simulated **3 transition pathways** aiming to transform the energy landscape in Megalopolis. The premise of this modeling exercise is that citizens must first recognize the benefits of investing in new energy products and services to actively engage in the energy transition. DREEM’s innovation lies in its versatility, enabling the assessment of not only technological infrastructure but also of business models and regulations that enhance the value of energy products and ensure fair compensation for all stakeholders involved.



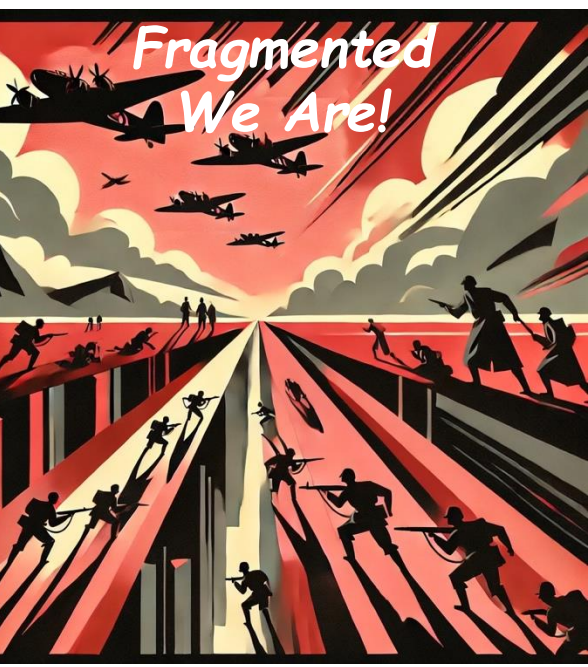
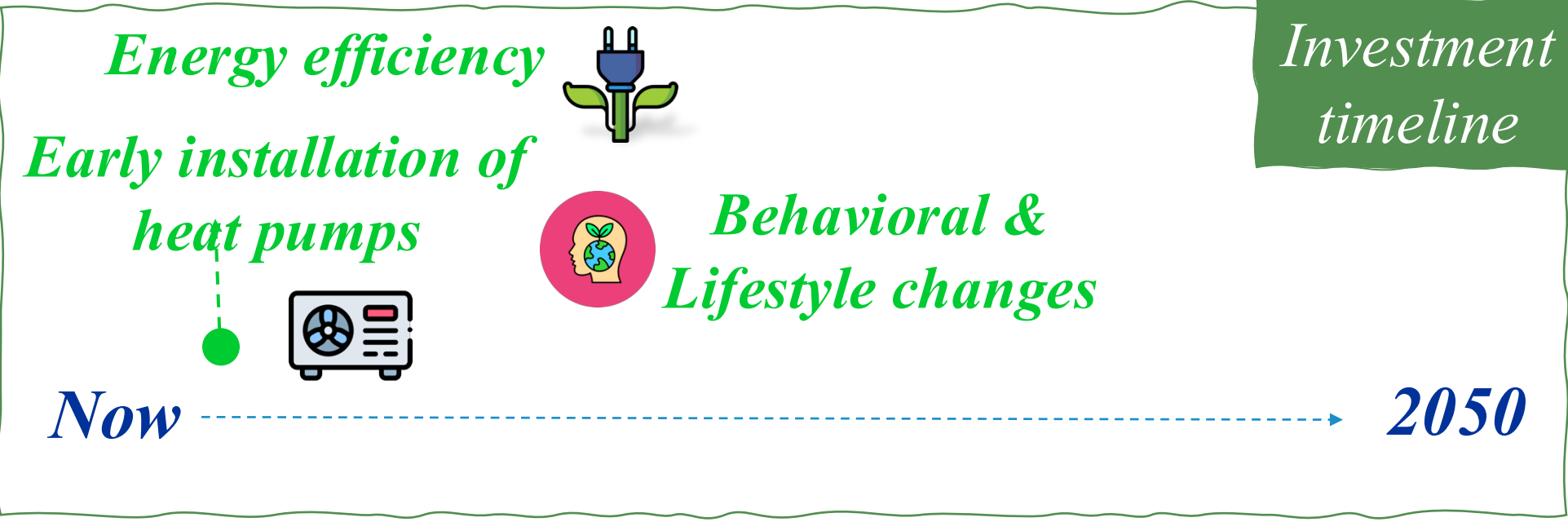
“Future-world” narratives & Transition pathways

The modeled transition pathways were developed according to the ENCLUDE’s **“future-world” narratives**, essentially exploring **3 different transition strategies** followed by the local community in Megalopolis, based on different motivations and social beliefs. These are assessed in terms of their potential benefits and drawbacks regarding their economic viability and impact on citizens, as well as their environmental footprint.



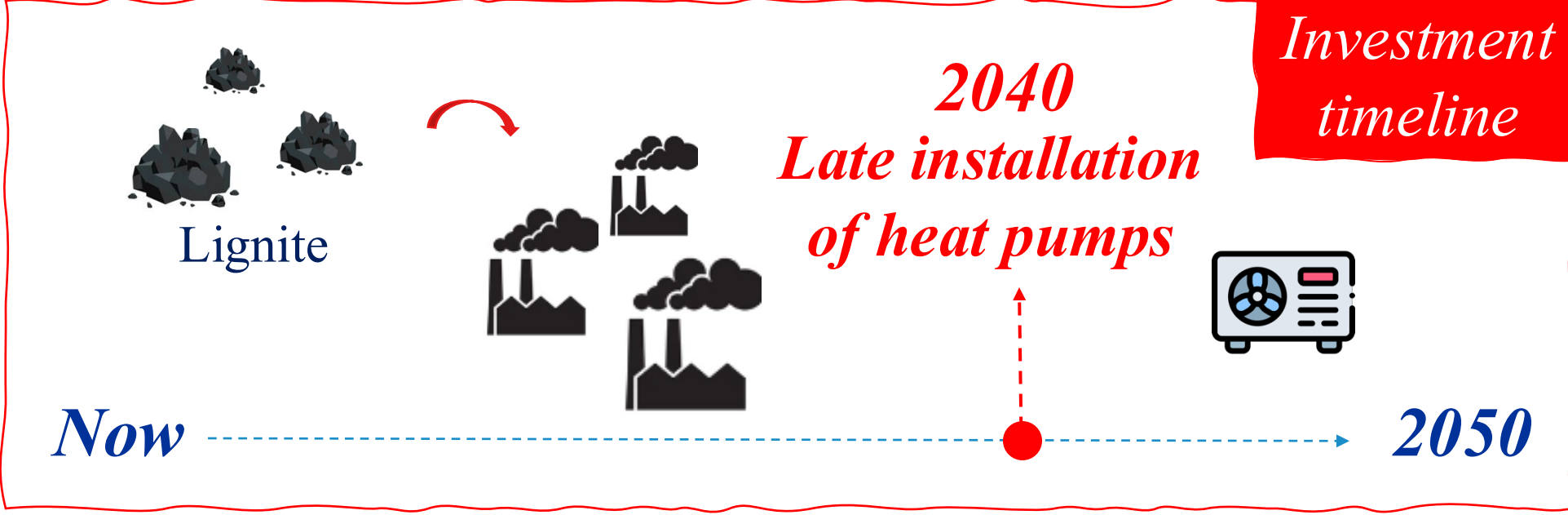
PROACTIVE CLIMATE ACTION? “A Unified World”

This transition pathway builds on the premise that **citizens come together united** in the battle against climate change and decide to **invest in green solutions** (energy efficiency upgrades and electrification, i.e., heat pumps) as soon as possible, while they are also willing to adopt behavioral and lifestyle changes when it comes to managing their energy consumption patterns.



DOUBLE DOWN ON FOSSIL FUELS? “A Fragmented World”

This transition pathway envisions a future marked by distrust and skepticism, where individuals prioritize **energy security** and **lower bills** over climate action. Due to the potential worldwide disparities and the resulting energy crises, people turn to **conventional sources** of energy more and more, despite their increasing prices. The latter leads to the introduction of green solutions as heat pumps **in 2040**, at half the rate compared to the situation under the “Familiar World” narrative.



Results

Energy mix, benefits & decarbonization potential

In the *“Unified World” narrative*, citizen investment in green technologies could **rapidly phase out fossil fuels in Megalopolis by 2050**.

In contrast, the *“Familiar World” narrative*, driven

by existing decarbonization efforts and policy-driven investments, may also achieve residential decarbonization by 2050, **but at a much slower pace**.

As a result, while both narratives ultimately attain similar emission reductions, the *“Unified World”* achieves significant emission cuts by **2030**- a milestone the *“Familiar World”* narrative **doesn't reach until over a decade later**.

However, in a *“Fragmented World”* narrative,

fossil fuels persist in the energy mix in 2050, hindering decarbonization efforts.

Costs & Savings

The *“Unified World”* pathway, despite **higher upfront costs**, quickly leads to the lowest annual household expenses, projected to drop **below €1,000 by 2030**. Over time, households could save up to **4 times more** compared to the fossil fuel-dependent *“Fragmented World”* narrative.

Overall, a cumulative amount of **around €300 million** could be saved at the municipality level by 2050. Downscaling from the municipality to the household level, this is translated to total savings of **around €60,000 per household** (i.e., **~3 times the current GDP per capita in Greece**).

Conclusions

Considering that local economy, which is currently mainly dependent on the energy and the mining sector, will undergo an abrupt pathway towards the phase out of lignite, and that by 2025 (when lignite-fired units are expected to close) employment and income levels could be significantly reduced, a **citizen-led transition** like the one studied, could decrease households’ energy costs, limiting the effect of wage decreases, and thus providing a significant helping hand to the most vulnerable citizen groups.

Regions can achieve both sustainability and economic viability



Read our Deliverable for more information!

See results in the ENCLUDE interactive platform!

Images presented were created with the assistance of generative AI and DALL-E 2.



Combining “people-centered” storylines based on social innovations of energy citizenship with narratives of potential “future-world” evolutions towards transformative scenario design

Vassilis Stavrakas¹, Dimitris Fotopoulos¹, Nikos Kleanthis¹, Nicole van der Berg², BinBin J. Pearce³, Detlef van Vuuren^{2,4}, Alexandros Flamos¹

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² *Copernicus Institute of Sustainable Development, Utrecht University, P.O. Box 80.115, 3508 TC, Utrecht, The Netherlands.*

³ *TU Delft, Faculty of Technology, Policy and Management, Building 31, Jaffalaan 5, 2628 BX Delft, Netherlands.*

⁴ *PBL Netherlands Environmental Assessment Agency, P.O. Box 30314, 2500 GH, The Hague, The Netherlands.*



Introduction

Since early 2000s scholars have been increasingly recognizing the **limitations** of **traditional top-down** approaches to climate and energy policy, which fail to account for the *social & cultural dimensions of energy use and production*. Addressing this, the concept of *energy citizenship* has emerged and gained in recent years considerable attention due to its potential to bridge the gap between energy transition policies and social participation, by emphasizing the significance of participatory and democratic processes in decision-making.

Motivation

Discourse surrounding energy matters has predominantly centered on technical and economic considerations, often overlooking discussions on inclusive and democratic governance. This is also reflected in contemporary energy modeling practices and scenario-based research, where focus is primarily placed on the technological optimization and economic implications of the energy transition, often **disregarding social and environmental aspects**, and treating them as external narratives, only to be considered “*on-top*” of modelling results, serving merely as a perspective for discussing scenarios and narratives. Underrepresentation of such elements combined with disproportionate emphasis on technoeconomic factors can lead to **oversimplified models** and **scenarios** that **fail to inform policymakers** about the **multiple dimensions crucial** for achieving a **sustainable and inclusive energy transition**. In this respect, there is a growing body of research seeking ways to integrate social sciences into scenario-based exploration.

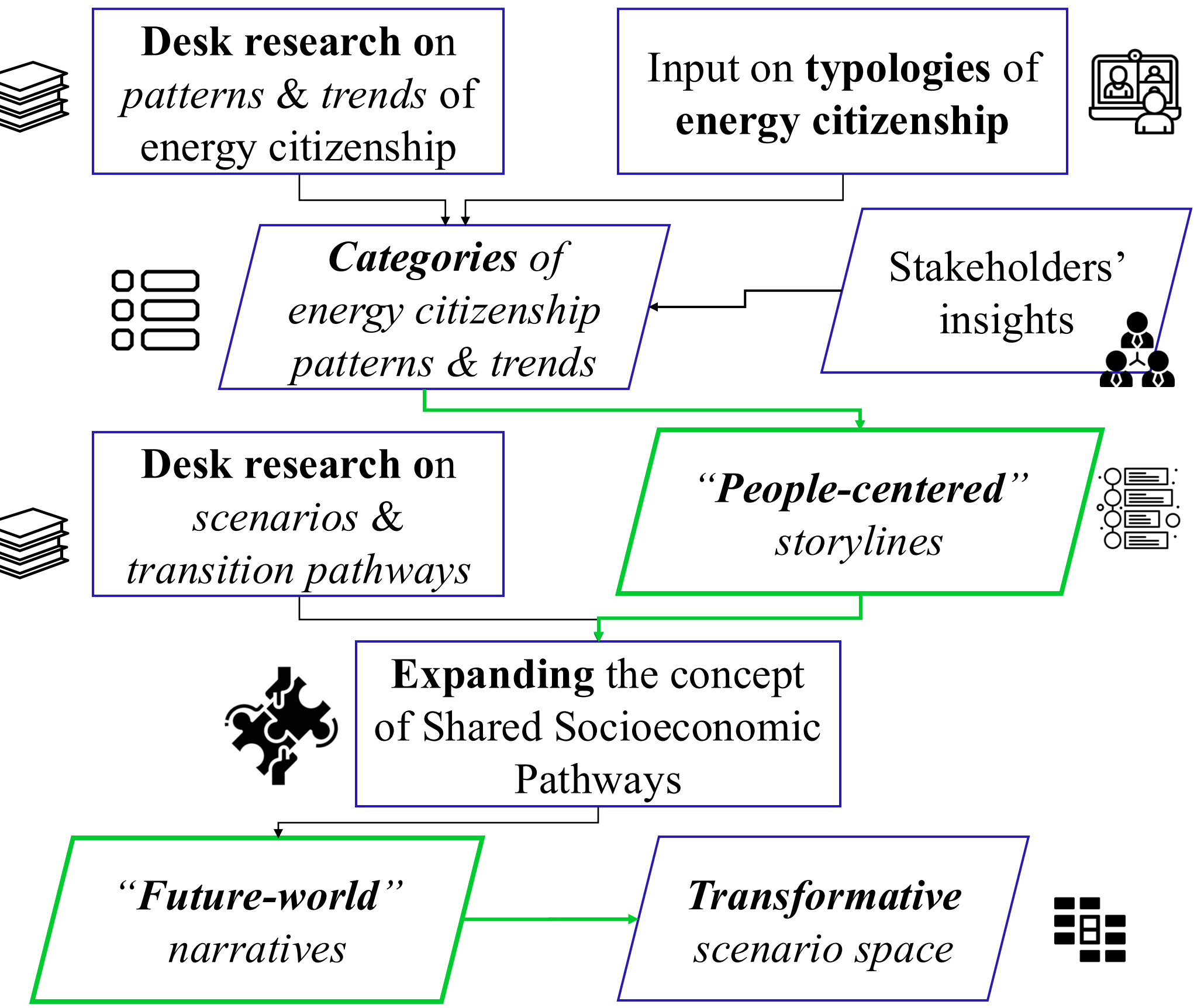
Scope

To this end, we present a framework for **transformative scenario design** based on **social innovations of energy citizenship** and **potential evolutions** of the **future**, which encompasses a broad spectrum of uncertainties and embraces the depth of complexity of the energy landscape, at the **local**, the **regional**, the **national**, and the **transnational** level. The developed framework does not only consider regulatory influences and technological advancements, but also delves into the *social, cultural, and behavioral* manifestations of *energy citizenship*, envisioning energy futures that *go beyond the comfort zone of current scenario-based research and examine out-of-ordinary extremes*.

Methods

To build the *scenario design framework*, we started with an extensive desk research into various *patterns & trends of energy citizenship*. This allowed us to capture and map the full range of citizen involvement in the energy transition. Considering stakeholders’ insights, we then grouped *patterns & trends* into *thematic storylines* that highlight both *individual* and *collective* actions.

Transformative scenario design should outline the transition to a decarbonized energy system while accounting for potential challenges and vulnerabilities humanity might face. To do this, we broadened the concept of the *Shared Socioeconomic Pathways*, to capture how various types of “**environments**” may influence the ways citizens engage in the energy transition.



Results

The “*People-centered*” storylines

➤ Individual level

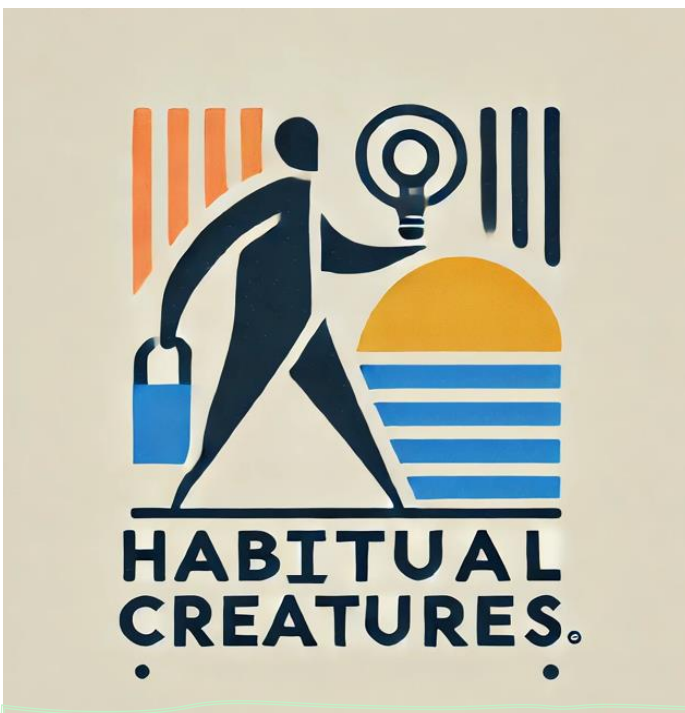


Power to the People

“A decentralized energy system where citizens become more actively engaged to the energy transition, investing in green technological solutions and relevant infrastructure”.

Associated
patterns & trends

- Investing in individual technologies, e.g., rooftop PV systems; battery energy storage systems; energy efficiency technologies; electric vehicles (EVs)



Habitual Creatures

“How daily habits of citizens and small changes in their lifestyles and behaviors can contribute to the decarbonization of the energy system”.

Associated
patterns & trends

- Incremental adjustments, e.g., thermostat adjustments; housing efficiencies: LED bulbs, standby mode appliances; shorter showers.
- Housing choices | Diet
- Leisure | Travel

➤ Collective level

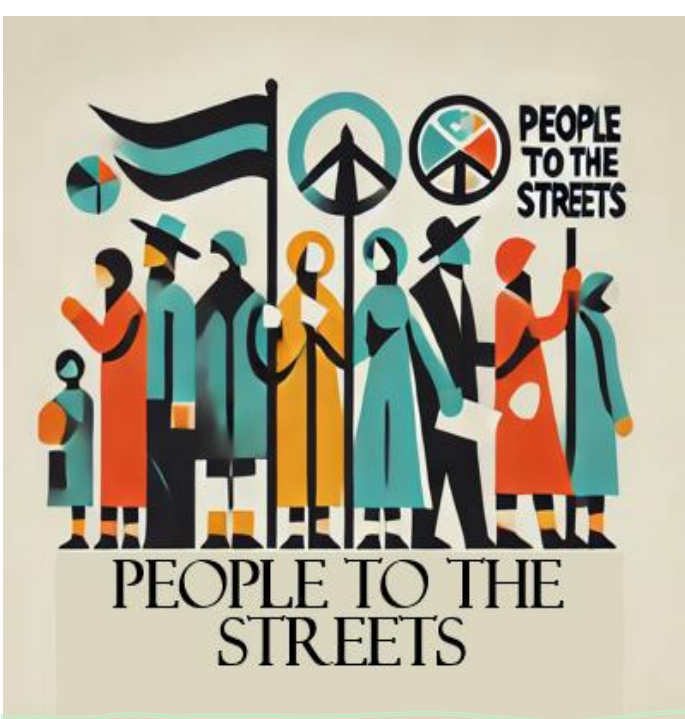


Band Together

“Citizen collective actions, such as the formation of collective energy initiatives (CEIs), like energy community and ecovillages, where optimized and localized energy production and resource utilization can take place”.

Associated
patterns & trends

- Communal technologies
- Communal investments
- Communal living
- Communal travel, e.g., car-pooling.
- Communal holidays



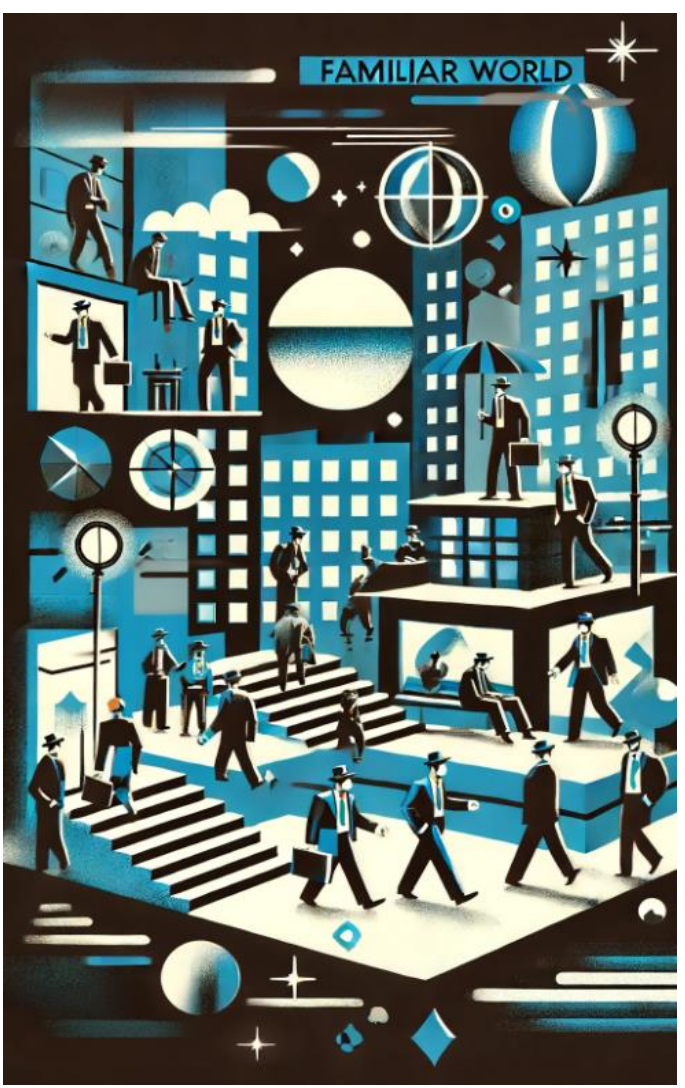
People to the Streets

“Political activism surrounding climate change and citizen participation in social movements and civil society initiatives advancing democratic visions of energy transition”.

Associated
patterns & trends

- Public awareness campaigns
- Advocacy and lobbying
- Shareholder activism
- Community lawsuits
- Protest and demonstrations

The “*Future-world*” narratives



A Familiar World

“The future-world evolution in its present state, with the current rates of decarbonization and the baseline scenario specifications as foreseen by current policy documents, relevant announcements, and political decisions made at the EU level”.



A Unified World

“A future-world evolution in which society, governments, and nations around the EU, but also at the global level, come together and unite against climate change, as the biggest crisis of our age. Policymaking processes all around the world promote acceleration of decarbonization through transnational collaboration and investments in green solutions as soon as possible”.



A Fragmented World

“Potential evolutions of undesired societies, which tend more and more to “dystopia” in the sense of extreme, or even exaggerated worst-case scenarios, e.g., more totalitarian regimes arise, more social inequalities, more control over people through the usage of propaganda, censoring of information or denial of free thought, gradual loss of individuality, enforcement of conformity, rise of individualism and anti-collectivism, etc. This narrative assumes that policymaking processes emphasize more regional and national security rather than combating the climate crisis”.

Conclusions

By combining the “*people-centered*” storylines with the “*future-world*” narratives, a **2-dimensional scenario space** is created. This **transformative scenario space** allows for the development of comprehensive scenarios that capture the multifaceted nature of the *energy transition dynamics* surrounding energy citizenship.

To the best of our knowledge, this is the first time that a structured framework for the design of transition scenarios towards the *operationalization* and the *holistic understanding* of the decarbonization potential of *energy citizenship* is presented, also accounting for the **uncertainty** and the **dynamic character** of events surrounding the potential evolution of the future. The **novelty** of our work lies in the flexibility that the developed framework provides to potential users towards exploring “**what if**” scenarios of the decarbonization potential:

(i). attributed to **individuals’** decision-making, while keeping constant potential future evolutions of the surrounding environment,

(ii). attributed to **different changes** of the surrounding environment, as governmental and societal decisions, etc., while keeping constant individuals’ decisions and choices, isolating future conditions’ potential for climate change mitigation, and

(iii). attributed to **variance in both individuals’ decisions and choices and surrounding environment’s conditions**, enabling deep exploratory assessments of different potential futures, also accounting for future uncertainties and unexpected events.

See the framework in action on the ENCLUDE interactive platform!



Read more about the proposed scenario design framework here!

Images presented were created with the assistance of generative AI and DALL·E 2.



“Power to the People” transitions by 2050 in different European Union cities: Empowering prosumerism and citizen investments in photovoltaic and storage systems

Nikos Manias, Dimitris Papantonis, Vassilis Stavrakas, Alexandros Flamos

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Introduction

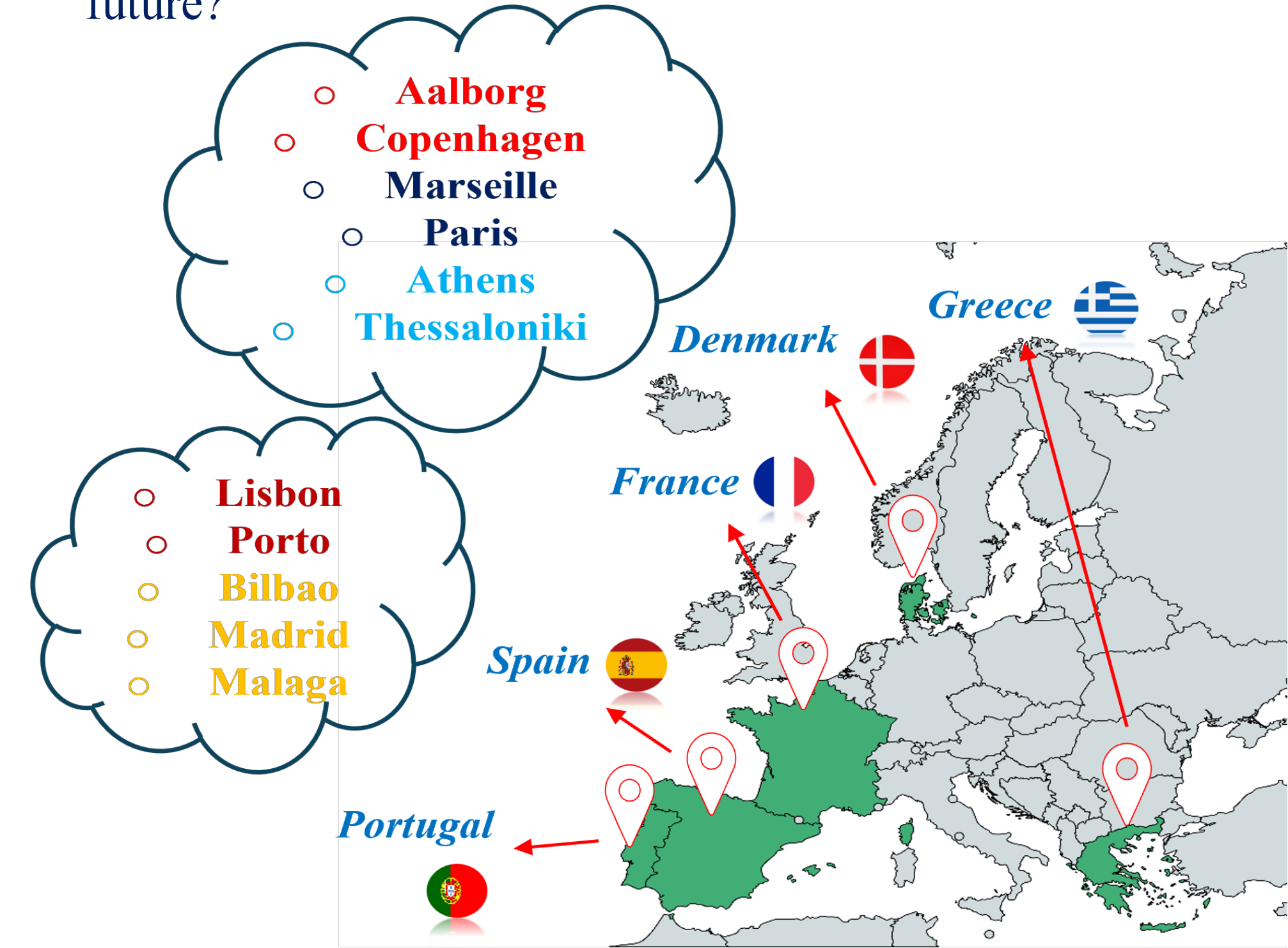
Imagine an EU where every household plays a pivotal role in shaping a sustainable future, where rooftops gleam with solar panels, transforming solar irradiation into clean energy. This is not a far-off dream, but an attainable reality through the power of **prosumerism**. As the EU pushes toward its ambitious goal of **climate neutrality** by 2050 through multiple packages, residential sectors stand at the forefront of this transition.

Empowering prosumers- who produce, consume, and even sell renewable energy- is more than just a trend; it's a game-changer. By fostering **local** and **national adoption** of **small-scale solar PV systems**, prosumers can help decentralize energy generation, reduce carbon footprints, and promote energy independence. Across the EU, these localized energy producers hold the key to accelerating the shift toward a low-carbon future, enabling the residential sector to become both energy-efficient and climate-neutral.

In a rapidly evolving energy landscape, the EU's commitment to empowering prosumers can transform homes into mini power stations, sparking a continent-wide energy revolution; one that brings the 2050 climate goals within reach, powered by the sun and **driven by the people** as **active EU energy citizens**.

Research questions

- ✓ How could different **policy schemes** empower prosumerism and further citizen adoption of small-scale PV systems by 2030 in different cities across the EU?
- ✓ What is the **emission reduction (decarbonization) potential** of different transition pathways at both local and national levels in different cities across the EU?
- ✓ What are the potential **benefits of prosumerism for European citizens** under different potential evolutions of the future?



Methods

By matching different energy citizenship trends and patterns with the Dynamic high-Resolution dEmand-sidE Management (**DREEM**) model, we calculated **economic benefits** for prosumers in different cities of **Denmark, France, Greece, Portugal, and Spain** taking into account existing regulatory frameworks in these spatial contexts.

Citizens must first see the **tangible** benefits of investing in new energy solutions to truly take part in the green transition through prosumerism. This is where DREEM stands out, by using the model to not only assess the technical side of energy infrastructure but also explore different **business models** and **regulations**. By doing so, it maximizes the value of energy products and guarantees fair returns for all actors involved, ensuring that everyone benefits from a cleaner energy future.

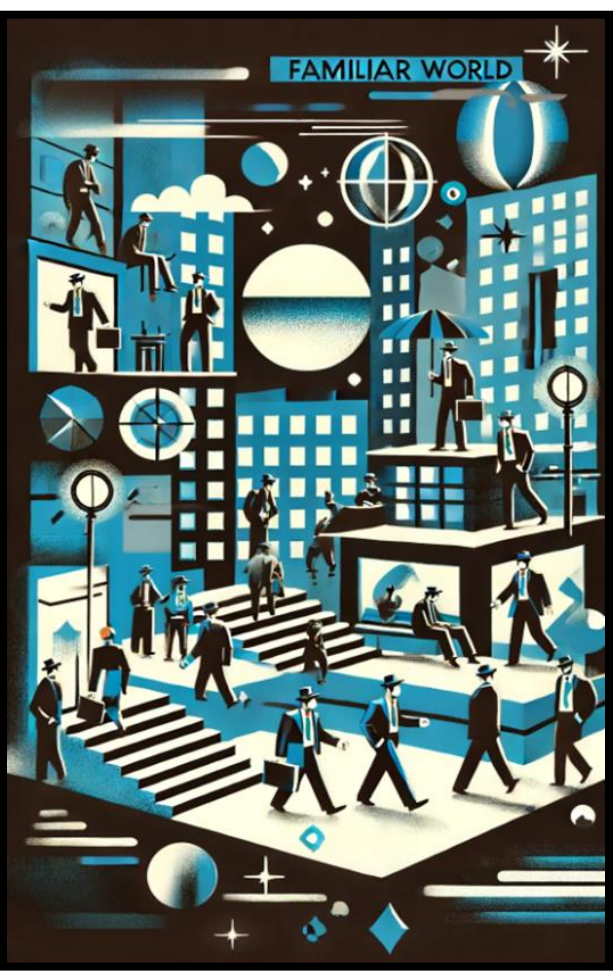
Furthermore, we have combined cutting-edge technology with real-world energy citizenship trends through the Agent-based Technology adOption Model (**ATOM**). By obtaining realistic uncertainty bounds and splitting the total model's output uncertainty in its major contributing sources, ATOM offers a glimpse into the future of residential energy transitions.



With ATOM, we don't just predict adoption rates; we also estimate the carbon emissions that could be slashed by empowering prosumers. It's a **data-driven blueprint** for a cleaner, greener EU, where individuals take charge of their energy futures.

“Future-world” narratives & transition pathways

Modeling exercises were conducted according to **3 different possible evolutions** of the **future world** that could shape the EU's energy landscape.



THE ROAD WELL-TRAVELED “A Familiar World”

European citizens stick to what they know, steadily adopting rooftop solar PVs based on tried-and-true benefits. With a solid understanding of how solar panels can lower their bills and reduce their carbon footprints, they make the shift at a pace that mirrors national and EU policy planning at their countries.

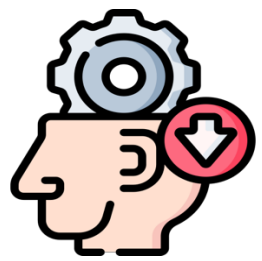
ONE PLANET, ONE FIGHT! “A Unified World”

In a world where knowledge is power, European citizens are making smart choices for their homes and their future. Armed with a clear understanding of the economic savings and environmental perks of rooftop solar PV systems they are seizing the opportunity to harness the sun. With electricity prices and costs of solar technology and battery energy storage systems (BESS) falling, the moment is ripe for action.



A WORLD SPLIT ON CLIMATE ACTION “A Fragmented World”

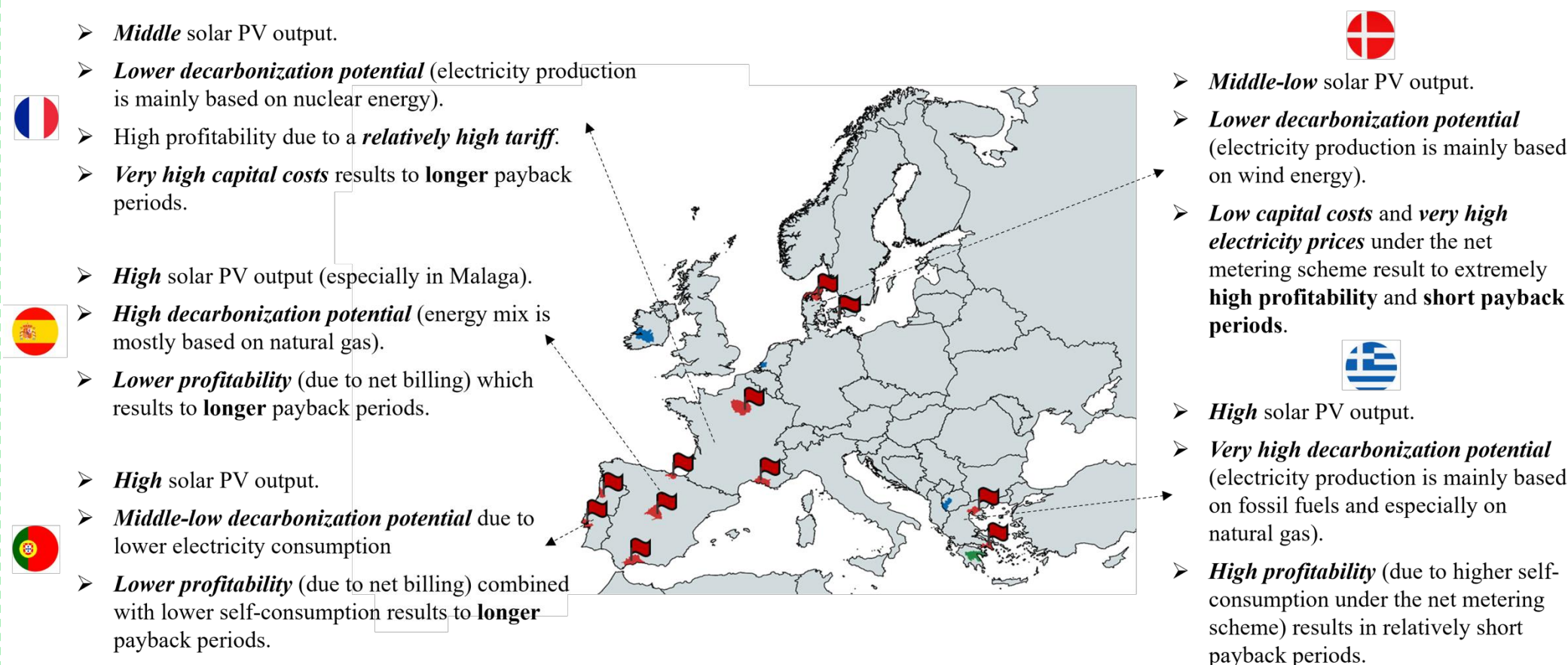
In a fragmented world, where tensions run high and priorities shift, European citizens hesitate to embrace rooftop solar PV systems. The increasing costs of solar PV and BESS further dampen enthusiasm, leaving households reluctant to invest. In this divided landscape, the potential of solar energy goes untapped, as uncertainty and lack of trust overshadow the benefits of going green.



Results

Economic & environmental benefits of prosumerism at the local level

Cross-country comparison



Modeling outcomes showed that the profitability of empowering prosumerism through citizen investments in small-scale/ rooftop PV systems at the local level and the EU cities under study depends on the policy schemes of use and capacity of the PV system. More specifically

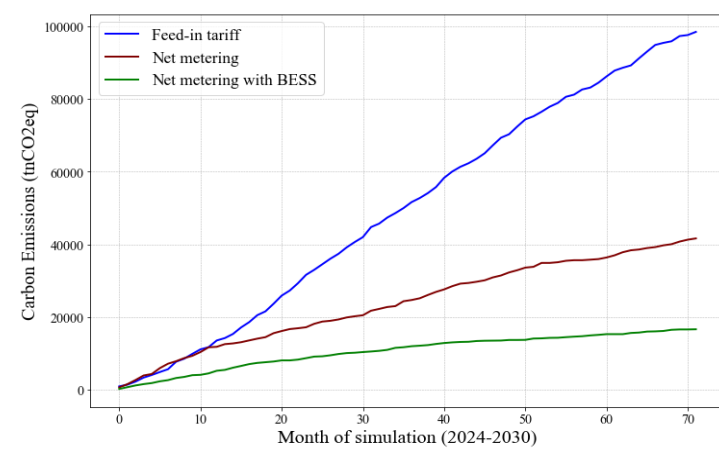
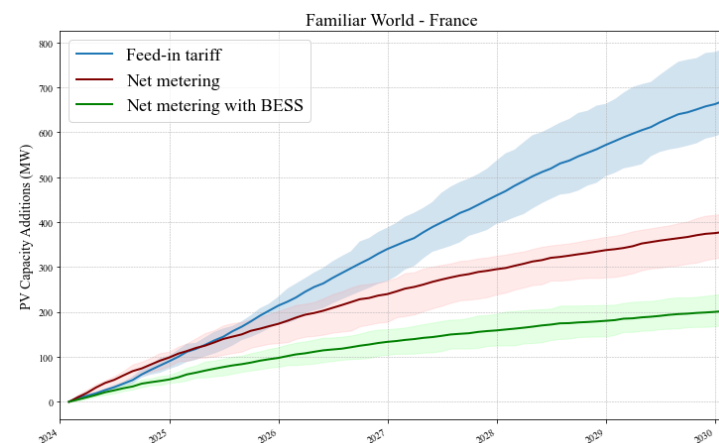
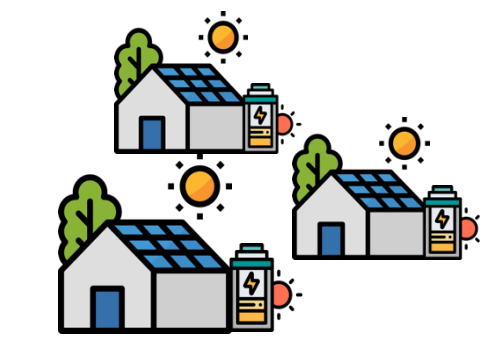
- Current **net metering** schemes appear more financially attractive when citizens invest in capacities of around **3kWp**, which provide the lowest payback period (roughly an average of 3.5 years across all case studies under the “Familiar World” narrative).

- Current FiT schemes tend to yield higher profitability when citizens invest in larger PV systems' capacities (>4kWp), especially when featuring a high fixed price for remuneration, as citizens are incentivized to generate greater electricity volumes to channel to the grid.
- Current net billing schemes in Portugal and Spain fall short when it comes to empower citizen investments and people-powered transitions based on prosumerism, as excess electricity is currently sold back to the grid at its wholesale price rather than at its retail price, resulting in longer payback periods.

Small-scale solar PV adoption & decarbonization potential at the national level

Prosumers are mostly keen on investing in rooftop solar PV systems when under **FiT** with large amounts of fixed prices.

However, **uncertainty is larger** in **FiT** due to its “static” nature compared to the “dynamic” nature of net metering.



Prosumers have a **clearer perception** about the **profitability** of their **investment** under **net metering** where profitability of investing is linked to the amount of electricity prices that citizens are called to pay.

A 100% subsidy on the BESS costs affects (positively) the “**psychology**” of prosumers, even when compared with a 90% subsidy; as observed in the case of Greece.

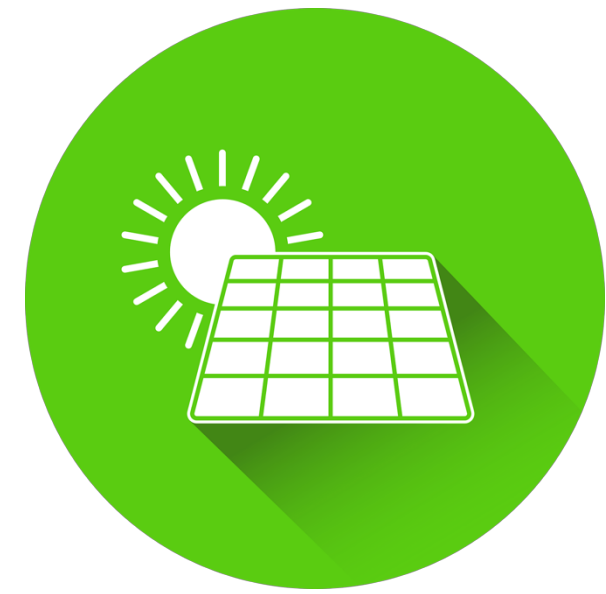


In all EU cities, rising with the sun, opportunities rise too!

Conclusions

The results of this work reveal ways in which the presented approach can be useful in formulating policies to empower prosumerism, as it can:

- ✓ **Recognize** that *citizens as prosumers have the power to influence and shape the future of electricity supply*, even in a possible “dystopian” future world.
- ✓ **Prioritize** the need for *long-term fixed prices for feed-in tariffs* since short-term may have a negative effect on the psychology of prosumers.
- ✓ **Identify** the need for *even more generous subsidies on BESS costs* for enhancing grid stability and flexibility.



Prosumers are protected from possibly elevated electricity prices!



Read our Deliverable for more information!

See results in the ENCLUDE interactive platform!



Images presented were created with the assistance of generative AI and DALL·E 2.



Combining “Power to the People” with “People to the Streets” storylines towards people-centered and 100% renewable-based national energy systems

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Introduction

Citizens in Greece could drive the **transition** to a **100% renewable national energy system** by supporting decentralized energy planning, which emphasizes local ownership and decision-making. By advocating for small-scale renewable energy sources like rooftop solar PV, communal energy projects, and efficient self-production schemes, they can help **reduce reliance** on **large energy corporations** and **ensure** that energy remains **closer to the people**. This grassroots approach ensures that energy benefits are distributed more **equitably**, fostering **community** empowerment, and making the energy transition more **inclusive**.

In addition, citizens in Greece could influence policy developments at different scales by participating in public debates and organized **movements** against **centralized, fossil-fuel-based** energy models. By raising awareness through **protests, social media**, and community **engagement**, they can pressure policymakers to prioritize renewable energy investments that reflect local interests and climate and environmental concerns. This collective citizen action can help shift the focus away from centralized, top-down approaches that often overlook the **needs** and **preferences** of local communities.



Citizens can also contribute by pushing for energy policies that promote decentralized, renewable energy systems. By voicing opposition to **large-scale, top-down** renewable projects like onshore wind farms that may not align with local priorities, they can advocate for a more democratized energy system. Supporting the development of a 100% renewable energy mix, the energy transition in Greece is not only environmentally sustainable but also **socially just** and **aligned with citizen values**.

By embracing decentralization, advocating for local renewable solutions, and demanding policies that prioritize people over corporations, Greece can transition to a 100% renewable energy system that's built by and for its people.

Research questions

- ✓ How does **citizen participation** in power sector planning and decision-making affects the capacity requirements and the resulting **electricity mix** of **decarbonization pathways** under different potential evolutions of the future?
- ✓ How do **costs** and the **carbon footprint** of **centralized** and **decentralized systems** compare between different future-world evolutions?
- ✓ What are the potential **socioeconomic benefits** derived from **citizen-led investments** and how do these benefits compare among different policy mixes and potential future evolutions of the surrounding environment?

Methods

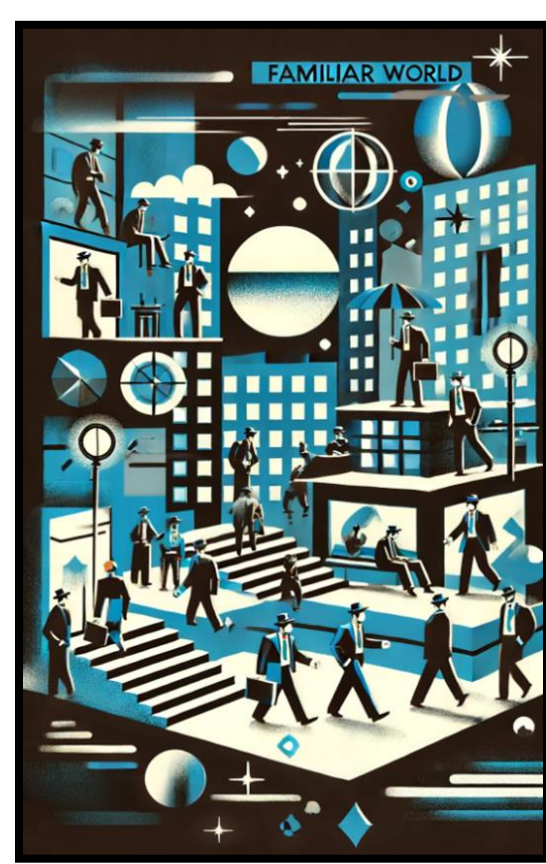
The **Open-Source energy MOdeling SYStem for GReece (OSeMOSYS-GR)** is a country-specific implementation of the OSeMOSYS model generator.



OSeMOSYS-GR accurately models the unique characteristics of the Greek power system for the period 2021-2050. Each year is broken down into 48 time slices, reflecting different parts of the day, spread across the months of the year. The model simulates the capacity requirements for, and the electricity generation from, different technologies, both fossil-fired, like lignite, natural gas, and oil power plants, and RES-based, such as hydro, onshore and offshore wind, utility, commercial, and rooftop solar PV, biomass, and geothermal. It also incorporates various flexibility options including pumped hydro, battery systems, and hydrogen systems powered by electrolyzers and fuel cells.

“Future-world” narratives & transition pathways

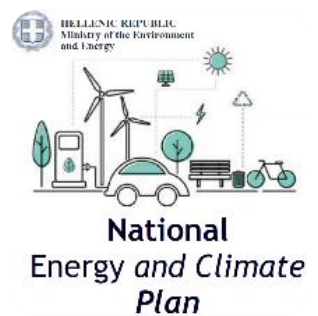
This modeling application was conducted considering **3 different possible evolutions** of the **future world** which can shape energy landscape in Greece.



FOLLOW EXISTING GOVERNMENTAL PLANS?

“A Familiar World”

Citizens depend on national political decisions to invest in green solutions. By keeping people informed about the energy shift, the government slowly builds support, easing the rollout of RES projects. As awareness grows, opposition fades, and the path to decarbonization becomes clearer.



ENERGY CITIZENS IN ACTION!

“A Unified World”

Citizens come together united in the battle against the climate crisis and collectively oppose to the use of fossil-fuels in the energy mix, thus leaving more room for RES. They quickly become prosumers, driving rooftop solar adoption through shared responsibility with governments and companies. Decentralized planning fosters even more citizen-led initiatives. With this collective push, decarbonization happens faster than expected, surpassing national-level projections.



ENERGY SECURITY BEFORE CLIMATE CRISIS?!

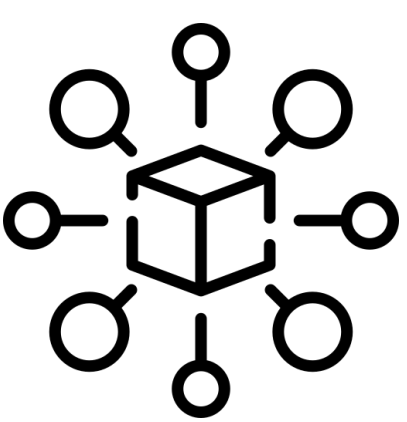
“A Fragmented World”

In this future, the energy crisis lingers, and thus citizens become distrustful and prioritize energy security over climate action. They back governmental plans that rely on fossil fuels, whether it is imported gas or domestic lignite. Prosumers emerge very slowly, driven more by peer pressure or economic necessity rather than a commitment to combating climate change. Rising energy costs further slow down the shift, making widespread prosumerism a distant goal.



Changes based on policymakers'/citizens' decision-making

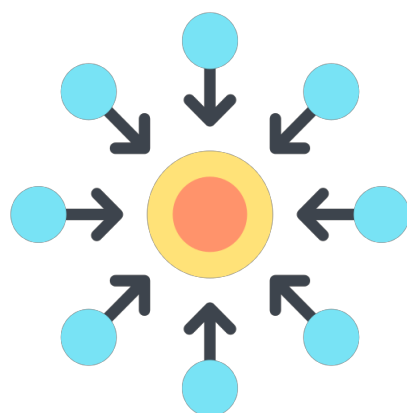
Decentralized Planning



In this scenario, citizens take matters into their own hands. In the “*Familiar World*”, they break free from the “*business-as-usual*” mindset, joining forces with policymakers to co-design a future that is less dependent on fossil fuels and driven by decentralized energy solutions.

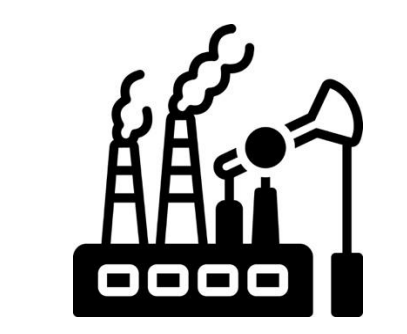
Meanwhile, in the “*Unified World*”, citizens unite against climate change. They collectively oppose to the use of all fossil fuels in the energy mix and push for a greener energy system through small-scale RES.

Centralized Planning



In the context of a “*Unified World*”, citizens unite against climate change and oppose the use of all fossil fuels in the energy mix, but they do not resist to large-scale RES project implementation.

Fossil fuel-dependent Planning



In the context of a “*Fragmented World*”, citizens are mostly concerned about their energy security and are supportive of basing energy planning on existing lignite and/or gas infrastructure.

Business-as-usual

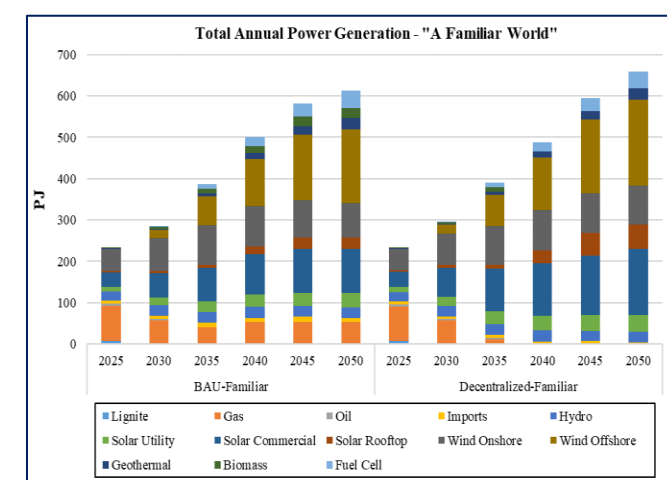
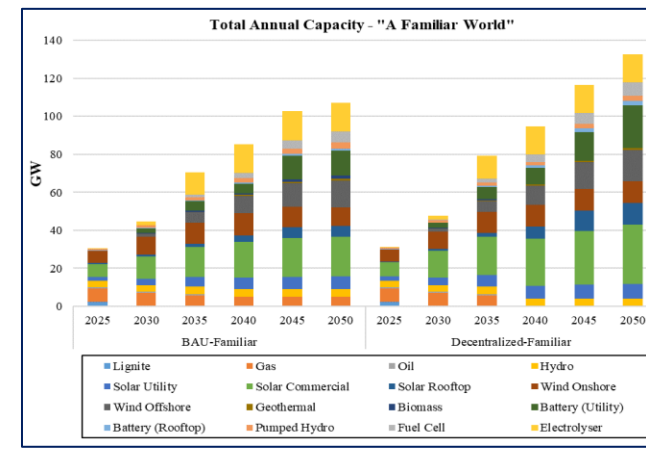


In the “*Familiar World*”, future energy planning follows the “*business-as-usual*” specifications. Citizens do not oppose the implementation of nationally planned energy projects.

Results

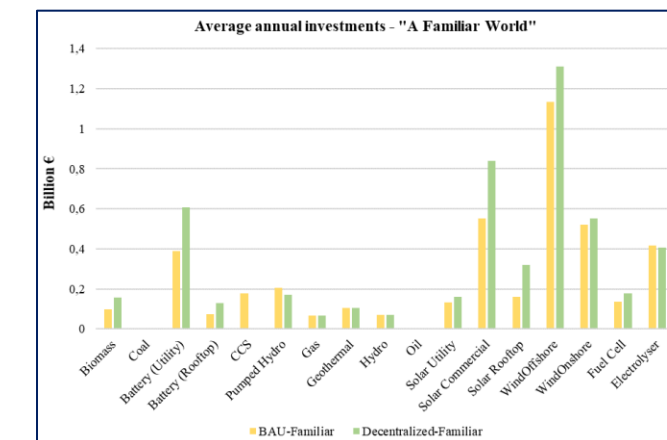
Electricity mix & power generation by 2050

Citizens' opposition to **large-scale energy projects** leads to larger capacity expansion of small-scale solar PV installations combined with storage and smaller capacity expansion of onshore and offshore wind.



A **decentralized power sector** will require more **short-term flexibility**, especially behind the meter, to improve night-time use of electricity, thus increasing self-consumption rates.

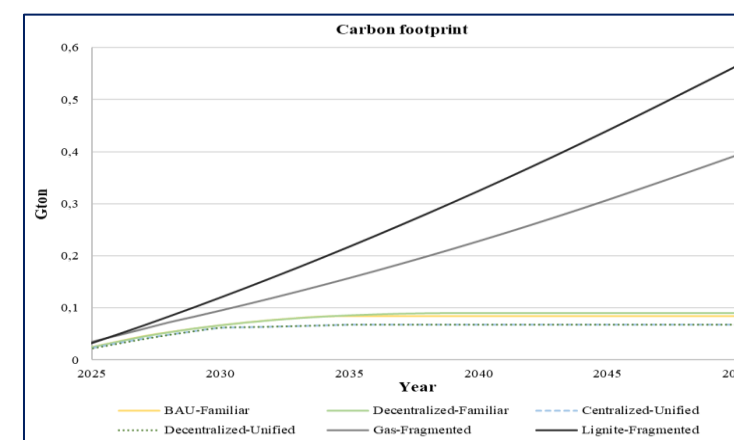
Capital costs & investments by 2050



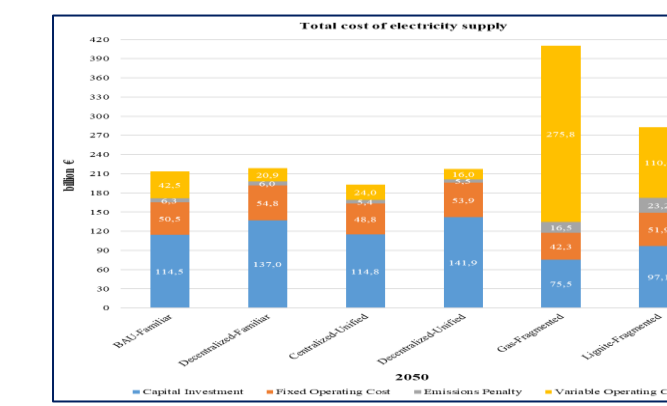
Decentralization of electricity generation will require significantly **higher capital investments in VRE** compared to more centralized system alternatives.

Carbon footprint by 2050

“**Fossil Fuel Dependency**” case poses the risk of resulting in extremely high total power sector **carbon footprint**.



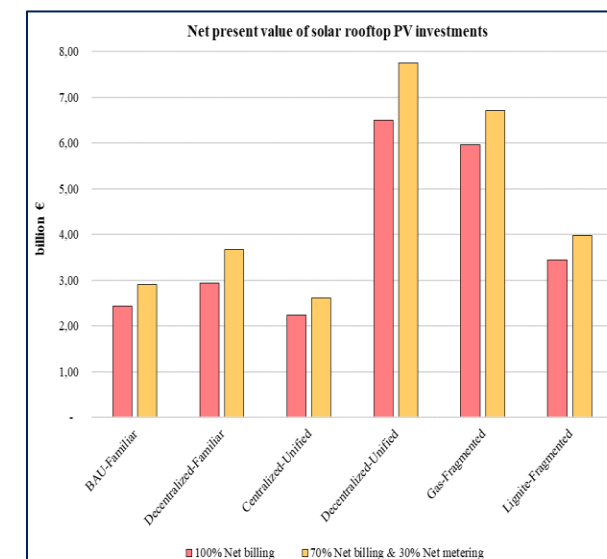
Total costs of electricity supply by 2050



“**Fossil-fuel dependency**” may lead to extremely high variable system costs, in case of future **energy crises**, that would lead to unbearable domestic electricity prices and increase **energy poverty**.

Socioeconomic benefits for citizens

The “**Decentralized**” case presents a more **democratized** and **equitable future** in which socioeconomic benefits are distributed between a larger share of citizens and thus **more people** can **catch up** with the **energy transition**.



In the “**Fossil-fuel dependency**” case only a **minority** of **citizens (innovators)** will highly profiteer by investing in rooftop PV systems due to the skyrocketing wholesale and retail electricity prices.

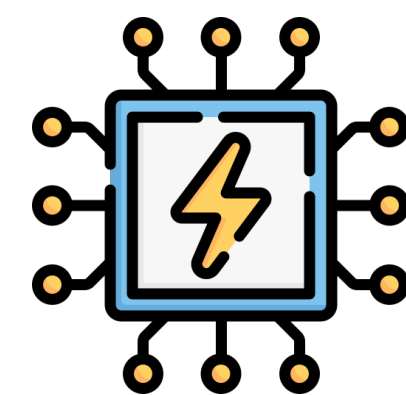
Conclusions

The results of this work reveal ways in which the presented approach can be useful in formulating policies on shaping the future energy system, as it shows that:

- ✓ Investment timing is a key factor for the energy transition since the earlier citizens start implementing solar rooftop PV investments **the higher the potential socioeconomic benefits** are going to be.
- ✓ “**Centralized**” energy systems lead to more **individualistic** and **unfair** futures in which socioeconomic benefits are distributed between a smaller share of people and thus **more people tend to be left behind** amidst the energy transition.



Read our Deliverable for more information!



See results in the ENCLUDE interactive platform!



Images presented were created with the assistance of generative AI and DALL-E 2.



Coupling machine learning clustering algorithms with energy simulation models to explore the decarbonization potential of strategic energy citizen clusters

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Introduction

A successful energy transition constitutes a deeply societal matter that has created the imperative to address its societal implications. In this regard, the European Union outlines policies that envision a central role for citizens in the energy transition and a more decentralized and democratic energy system that could encourage renewable energy production and empower citizens to engage and take responsibility for energy production and consumption. Aiming to realize this vision, the sociopolitical concept of “*energy citizenship*”, consistently resurfaces in recent scientific and political discourse, due to its potential to bridge the gap between energy transition policies and social participation by emphasizing the role that citizens can play through their engagement and involvement in the energy system.

In this study, we integrate *energy citizenship* trends and patterns into energy modeling to create more comprehensive and socially informed modeling exercises. This allows us to explore the multi-scale relationship between the various expressions of energy citizenship and their potential impact on decarbonization efforts under a variety of scenarios and external conditions.

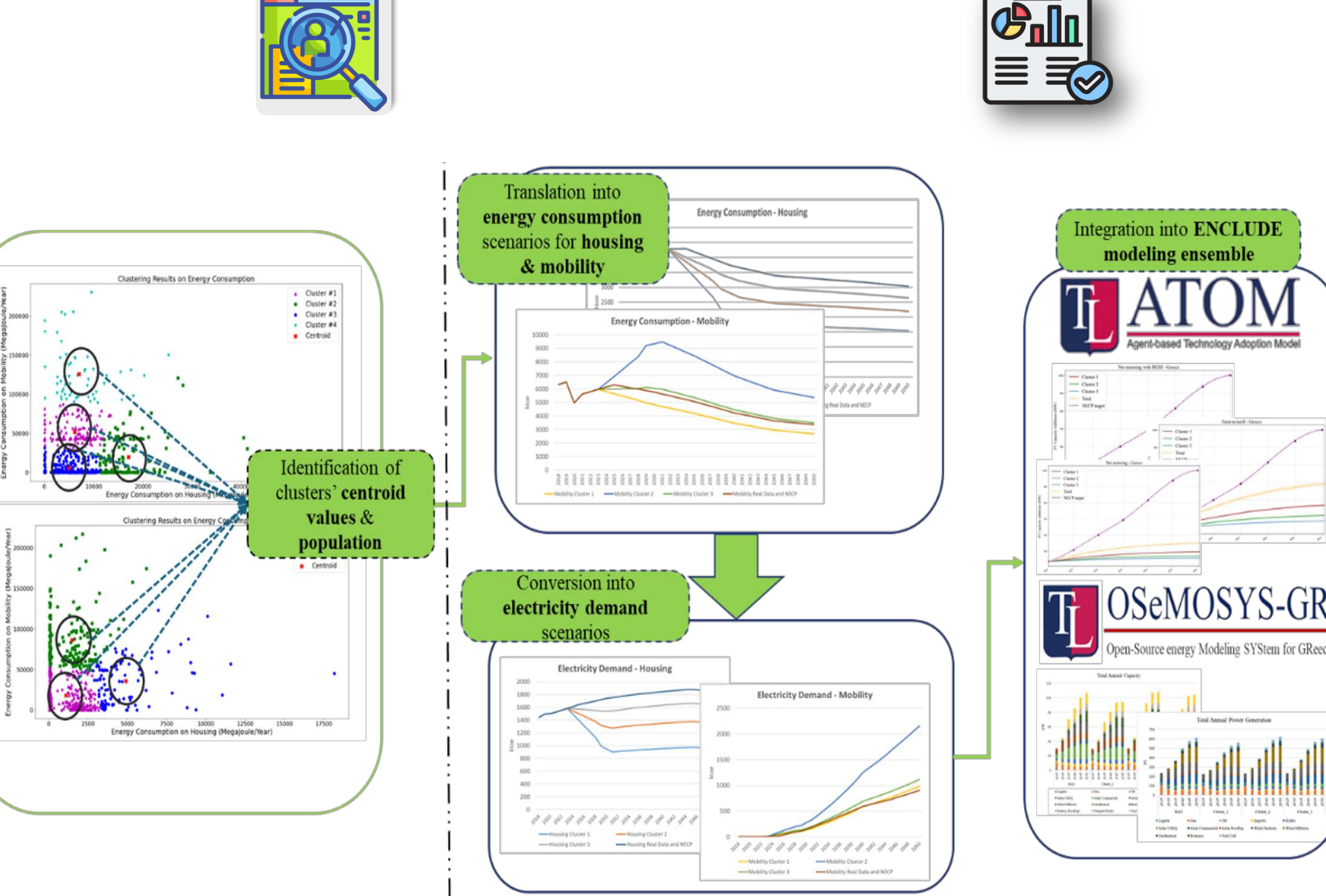
Aiming to further enhance this approach, we pair the strengths of energy simulation models with results derived from machine learning clustering algorithms. More specifically, by using machine learning algorithms, clusters of energy citizens are identified by utilizing data on energy consumption and carbon emissions for specific Member States. This results in the identification of commonalities within the utilized dataset and a subsequent categorization of citizens in distinct groupings.

Leveraging this work, we **integrate clustering and profiling results into energy system modeling and simulation tools**, by translating the clusters' characteristics and energy behaviors into inputs for the ENCLUDE modeling ensemble. This integration **quantifies the decarbonization potential of different citizen groups, and demonstrates which clusters are more crucial and responsive towards accelerating decarbonization efforts**. Targeting these clusters with tailored policies and interventions can significantly enhance the overall effectiveness and efficiency of decarbonization initiatives.

Methods

Assessing the decarbonization potential of energy citizen clusters requires a **multi-method approach**, involving both semi-quantitative and quantitative methods. Using the insights from citizen clusters as input for the ENCLUDE modeling ensemble, we managed to formulate questions and explore scenarios that could provide recommendations for the development of policies and strategies that effectively promote decarbonization efforts across different segments of the population. Our methodological approach consists of the following four steps:

- Step 1:** Understanding the citizen clustering and profiling analysis
- Step 2:** Adjusting the models to integrate the clustering results
- Step 3:** Case study selection and scenario design
- Step 4:** Model application to the case studies



Case studies

The case study selection aims to showcase diverse socioeconomic conditions, e.g., income, employment rates, etc., which should be taken into consideration when studying the transition to fair and inclusive future societies. Additionally, our analysis spans across different policy landscapes, considering various policy frameworks. Bound by the available clustering data, our research encompasses **two EU Member States**, and delves into the following *two* topics:

Adoption of rooftop solar PV systems in the housing sector for different energy citizen clusters in Greece and the Netherlands

Citizens are increasingly becoming individual owners of solar PV assets, thus consuming their own electricity and playing a supportive role in driving the energy transition. Considering that, we used the **Agent-based Technology adOption Model (ATOM)** to evaluate the adoption potential of small-scale solar PV systems in the residential sector in Greece and the Netherlands toward 2030. Specifically, we explored how different policy schemes can empower prosumerism and further citizen adoption of small-scale PV systems for different citizen clusters as well as their decarbonization potential.



Research Questions

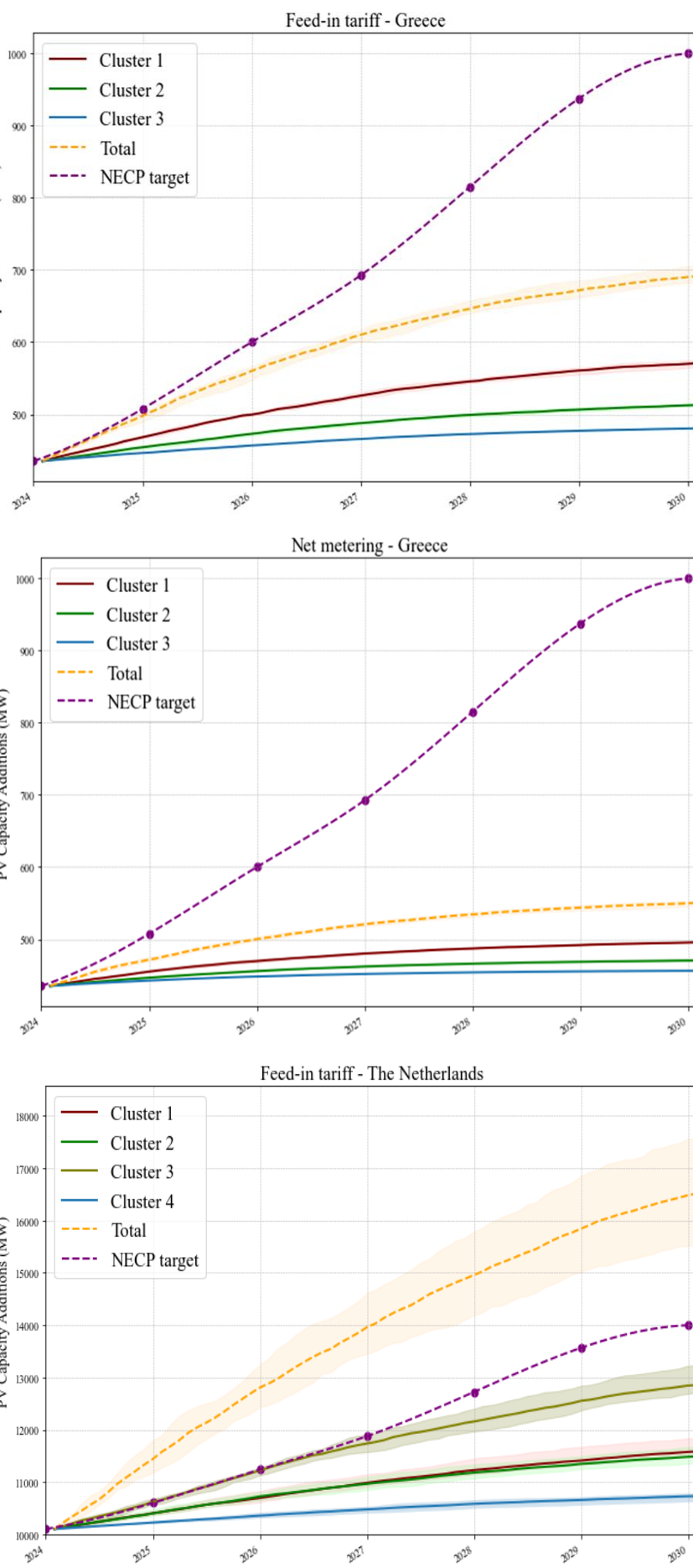
- How could different *policy schemes* empower prosumerism and further citizen *adoption* of small-scale PV systems in Greece and the Netherlands by 2030 for the different citizen clusters that have been defined?
- What are the *carbon emissions* that could be avoided through the further empowering of prosumerism in Greece and the Netherlands by 2030 for the different citizen clusters that have been defined?

Results

FiT policies have the **highest impact** on PV adoption in both countries, especially when combined with higher fixed rates.

The Netherlands can achieve its **ambitious 14 GW target** through either a FiT or net metering policy, while Greece faces a steeper climb to reach its target of 1 GW by 2030 and will **need to consider a strategic mix of policy supports**.

The **uncertainty ranges** for the PV capacity additions of the different Dutch clusters are higher than the Greek clusters, indicating that **Dutch** citizens feel **less secure** about the profitability of investing in PV systems despite the higher total PV capacity additions.



Conclusions

To maximize solar PV adoption, policy designs should focus on **households** with **lower-than-average** electricity consumption. Tailored incentives can drive adoption, making small-scale PV investments more attractive. Our recommendations to policymakers:

- Programs** providing **subsidies** for installation costs up to a certain capacity and/ or annual **rebates** on electricity bills up to a specific consumption level.
- Premiums** on net metering rates for electricity fed into the grid; **FiT** schemes offering higher fixed rates for small PV systems (<5 kWp).

The Netherlands



Power sector capacity buildout based on electricity consumption patterns of different energy citizen clusters in the housing and mobility sectors in Greece

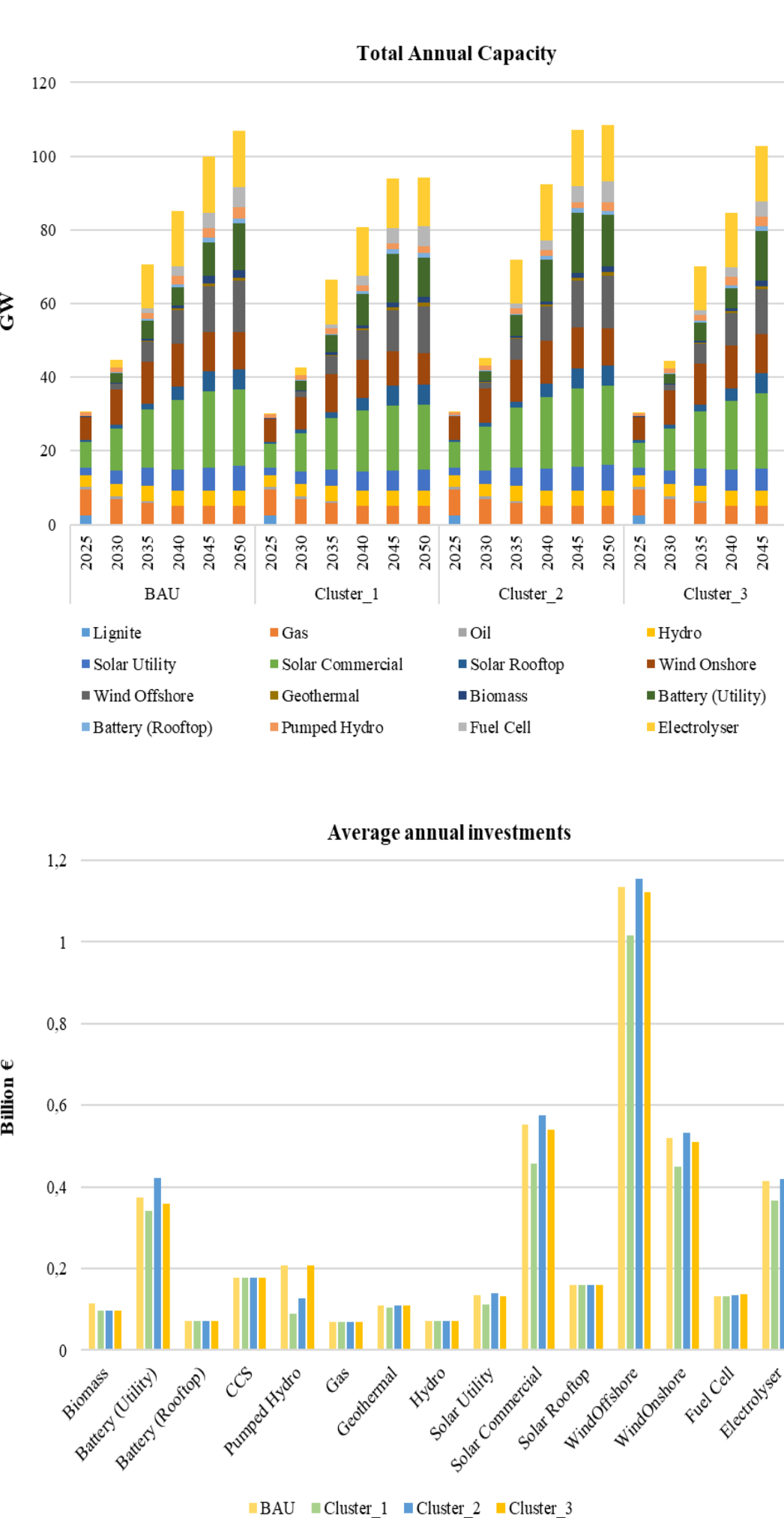
Citizens' adoption rate of electrification technologies and their energy use patterns will significantly impact the future energy system's design in terms of capacity and flexibility requirements. To better understand the potential impacts wielded by citizen groups with different sociodemographic characteristics, energy consumption levels, etc., we integrated identified citizen groups' energy consumption patterns into the **Open-Source energy Modeling SYSTEM for Greece (OSeMOSYS-GR)**, allowing us to explore decarbonization pathways in the Greek power system by 2050.



- How do different citizen groups' energy consumption patterns affect the *capacity* and *flexibility requirements* as well as the *resulting electricity mix* of decarbonization pathways in the Greek power sector by 2050?
- How do different citizen groups' energy consumption patterns affect the *capital investments* and the *carbon footprint* of decarbonization pathways in the Greek power sector by 2050?

Citizens' electricity demand profiles influence energy storage investment priorities: **sharper seasonal peaks** due to increased mobility demand favor battery storage, while **smoother peaks** due to increased housing demand, favor pumped hydro storage.

Citizen clusters with energy-sufficient behaviors contribute to lower power system costs and carbon footprint, while reducing housing and mobility sector costs and emissions as well as achieving **<12.5% savings in annual capital investments**.



For Greece to achieve carbon neutrality, policies must empower citizens to adopt **energy-sufficient lifestyles**. By aligning policies with these goals, Greece can transition to a more resilient, independent energy system. Suggested **sufficiency** policies for the housing and mobility sectors are:

- Housing:** Progressive tariffs favoring low energy use; Sustainable building practices; Policies for **home sharing** and **renovations**.
- Mobility:** Shift in investment toward **public transportation** and **cycling**; **Eco-design standards** for vehicles; Incentives to reduce private car dependency.

Explore our work in more detail here!



Explore the EnergyCitizenship.eu interactive platform!



Deriving Energy Citizens Profiles for Effective Energy Policies: Clustering Analyses on Quantitative and Qualitative Data

1. Introduction

- In the transformation of the energy system, the role of its citizens is becoming increasingly important through their engagement, involvement, and shaping of the future energy landscape.
- Identify groups of citizens (clusters for decarbonization) at different scales of analysis is key to inform a just energy transition.
- To this aim, clustering models (e.g., through Machine Learning (ML) methods) were developed and tested using existing and new EU citizens' datasets.

2. Analytical Framework

- A machine learning model was applied to quantitative data from the ECHOES ("Energy CHOices supporting the Energy Union and the SET-Plan") project to identify distinct clusters of citizens.
- Index-based clustering method was applied to qualitative data from the ENCLUDE data of citizens who have participated in energy initiatives.
- The k-means clustering method was adopted for both qualitative and quantitative data, using the elbow method to find the optimal number of clusters
- The ECHOES energy consumption of citizens was based on Life Cycle Analysis (LCA) for the mobility and housing sectors.
- The CO₂ footprint of ECHOES citizens was estimated on both sectors for clustering.
- Within-clusters statistics were then analyzed based on different sociodemographic and psychological attributes (e.g., age, education, car fuel efficiency, and climate change perception) to extract 'profiles'.
- Index-based clustering of ENCLUDE data was based on answers to questions in 4 categories: **Energy poverty, Mobility, Housing, and Climate Change Perception**.
- The overall data analysis framework is presented in [Figure 1](#).

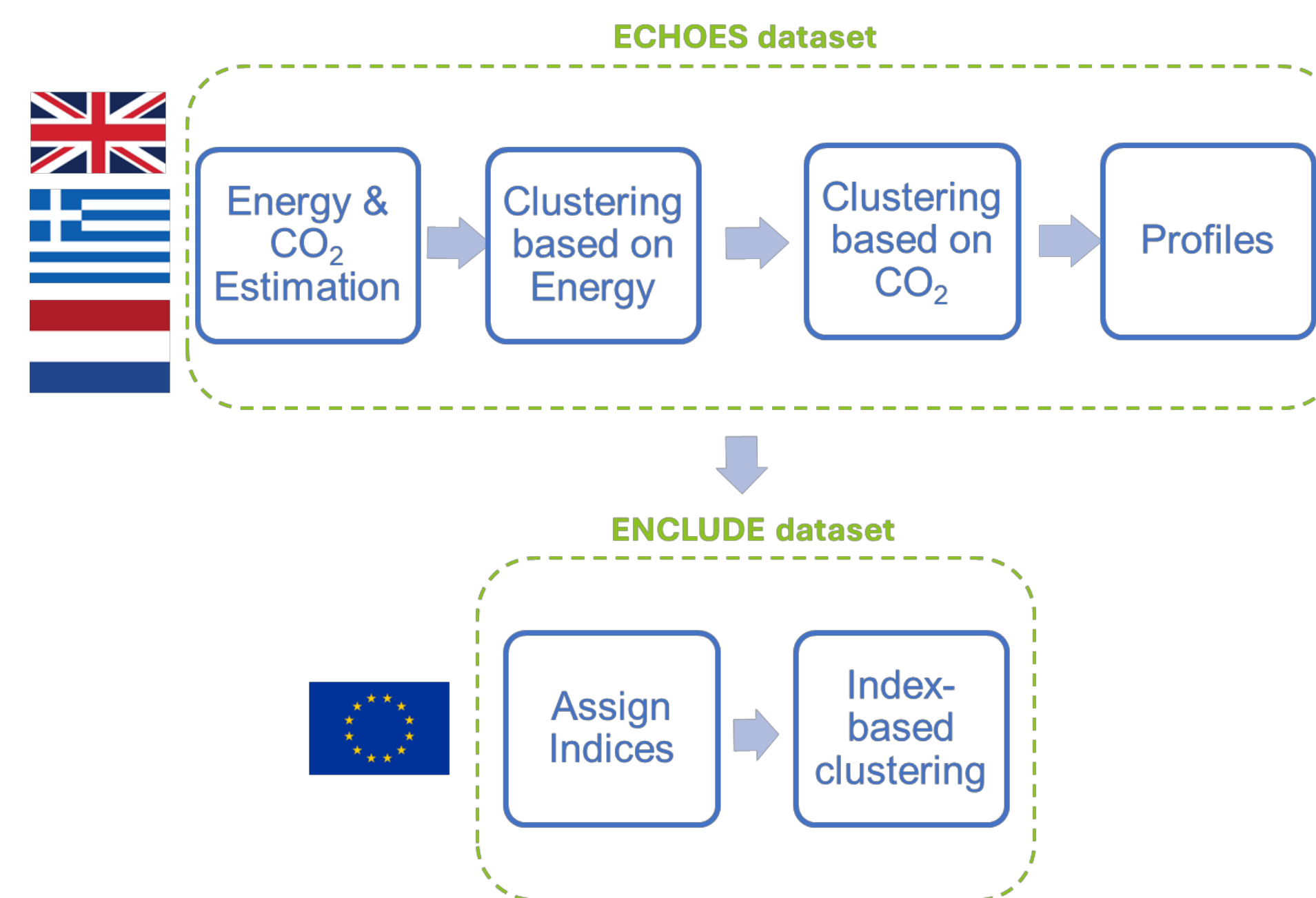


Figure 1 Overall data analysis framework for qualitative and quantitative data sets

3. Quantitative Data

The clustering results based on CO₂ footprint data for the UK are presented in [Figure 2](#), with [Figure 3](#) showing the citizens profiles emerging from the corresponding within-cluster analysis. The same procedure was implemented for Greece and The Netherlands.

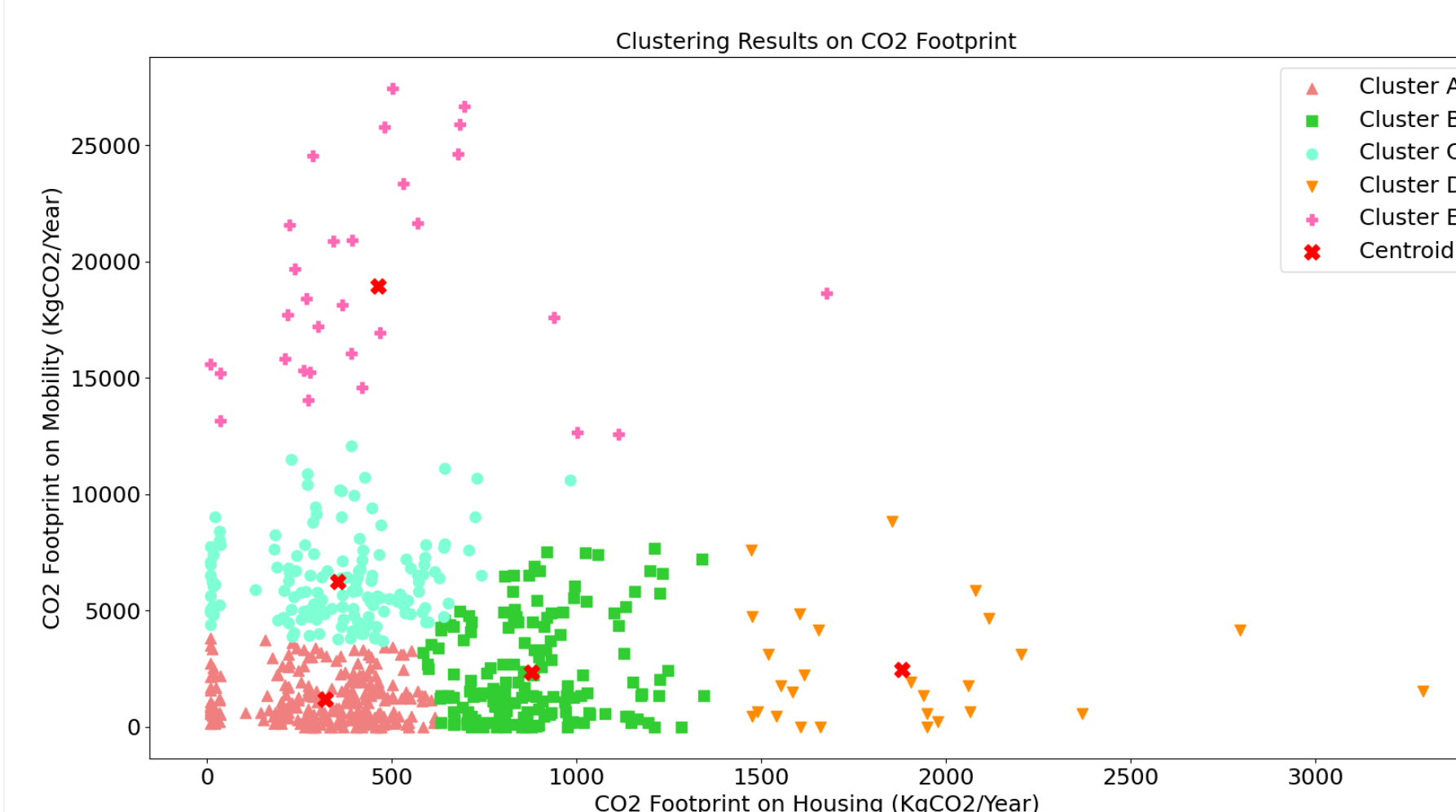


Figure 2 Clustering Results for the UK based on CO₂ footprint

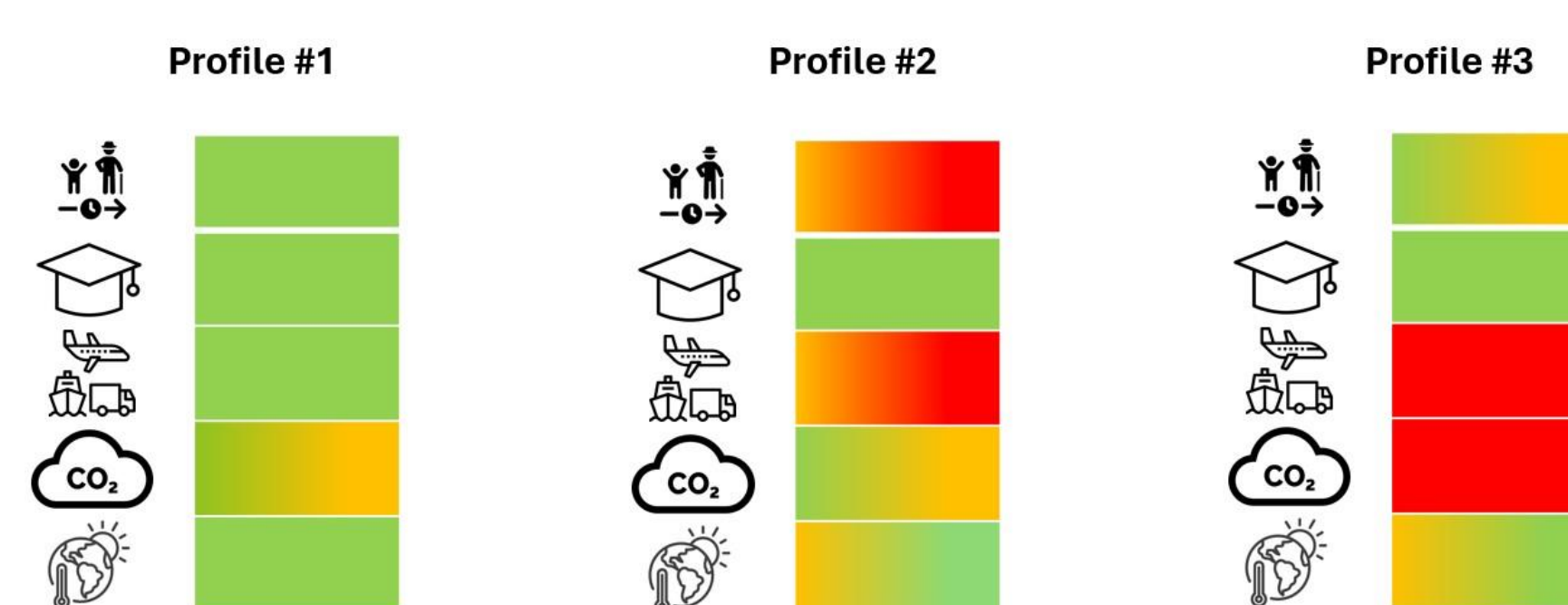


Figure 3 Energy citizens profiles for the UK, capturing age, education level, carbon intensity of energy consumption and attitude to climate change.

- Profile #1 mainly consists of citizens with low levels of CO₂ footprint on housing and mobility. This profile represents 65% of the population, with mostly young people with college degrees and low CO₂ emissions.
- The citizens in Profile #2 represent 30% of the respondents, who are both young and old people with medium to high CO₂ footprint on housing, but low CO₂ footprint on mobility.
- Profile #3 represents 8% of the population, consuming more energy on mobility and with a high level of CO₂ emissions on mobility.

4. Qualitative Data

ENCLUDE data were clustered via defined indices based on answers to questions in 4 categories: **Energy poverty, Mobility, Housing, and Climate Change Perception**.

4 indices for energy poverty index (EPI), energy on housing index (EHI), energy on mobility index (EMI), and climate perception index (CPI) were defined and rescaled to 0-100 for each respondent based on relevant questions to each index. The clustering results are presented in [Figure 4](#).

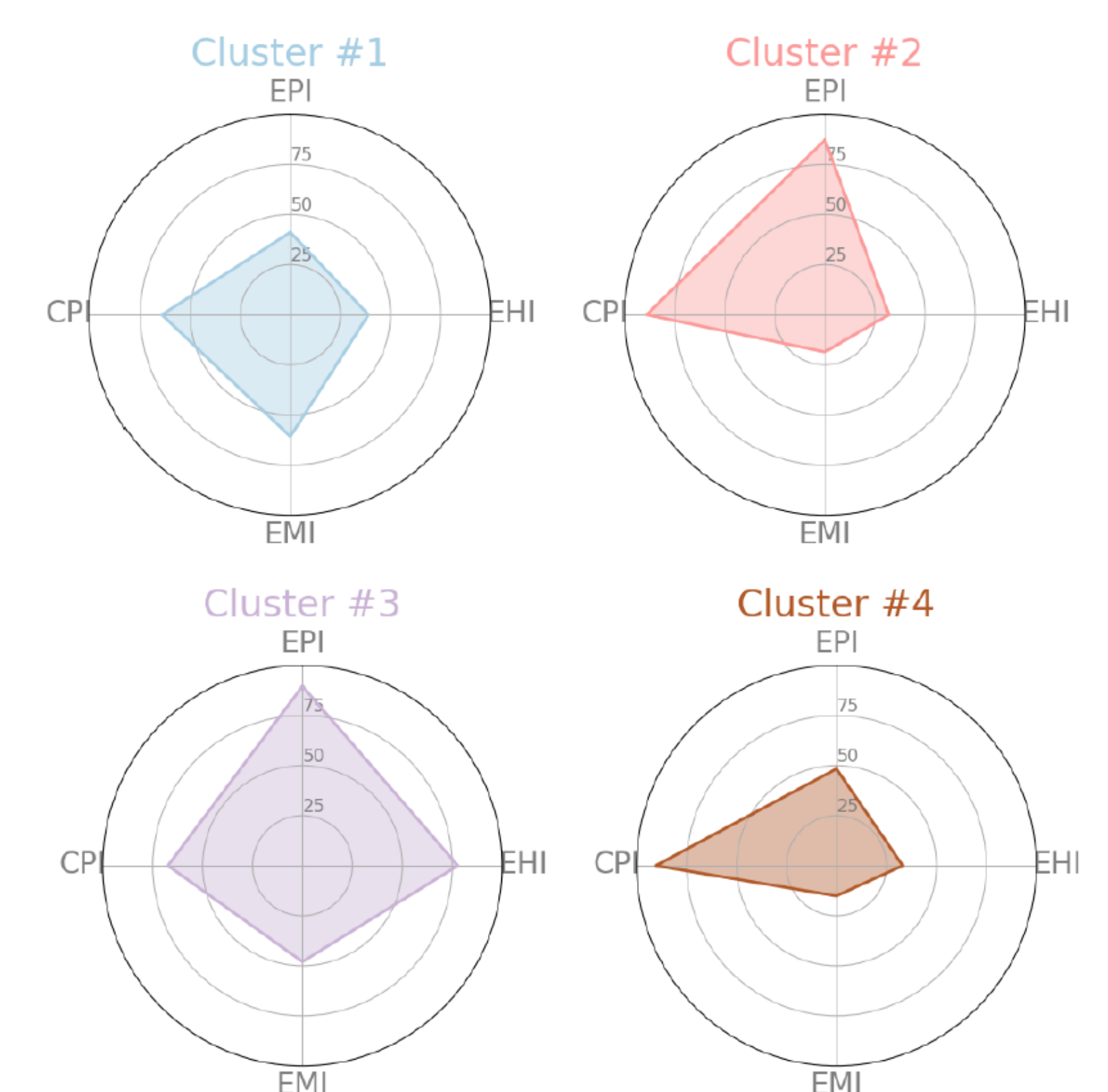


Figure 4 Spider plots of index-based clustering results for each of the four clusters

- Citizens of Cluster 1, with the highest EMI, mostly live in villages and are mostly young people and people older than 50, with a secondary education level.
- Citizens of cluster 3, with the highest EPI, are mostly old people living in villages where most of them are employed.

5. Conclusion

- Clustering can help to identify groups of citizens with similar energy consumption behaviours and their associated carbon footprint.
- Insights into sociodemographic and psychological attributes can be used to draw comprehensive narratives for energy models towards more realistic decarbonization scenarios which allow end-users (including policymakers) to identify optimal options.
- This proposed framework can be applied to more countries and/or new data sets to bridge to energy and scenario models at different scales (from community to district, city, national and super-national).