Democratise energy through energy activated citizens and data-driven communities: The ENPOWER approach

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***Abstract*— The need to ensure a just energy transition and shift towards decentralised energy systems is becoming crucial. The European Commission outlines the need for energy independence, based on two key pillars: (a) diversifying gas supplies; (b) reducing faster the use of fossil fuels in homes, buildings, industry, and power system, by increasing energy efficiency gains and renewables. Energy communities can be a pivotal mechanism in achieving this transition. However, the current social practices, technologies adoption and business models are not sufficiently mature to enable energy citizenship's practices scaling up and replication. There is a need to transform traditional passive energy consumers into active energy citizens enabling them to take full control of their energy usage. To do so engaging with all the principal actors of the energy value chain, and allowing them to achieve energy savings is needed, while increasing their energy efficiency and self-consumption optimisation and transforming energy consumers and communities to digitally enhanced and grid-friendly ones.**

Keywords—Energy democratisation, energy transition, data-driven energy communities, energy sector, active citizens

I. Introduction

Energy democracy has emerged as a critical concept in the discussion of sustainable and equitable energy systems, with its ability to promote socio-technical transformations. It sees the energy system as a complex interplay of technologies, human interests, wants, and mindsets that are all firmly rooted in historical and sociopolitical contexts [1-3]. As a term loaded with political significance, energy democracy is understood in various ways—be it as a process, an outcome, or an overarching goal—each interpretation reflecting the diverse contexts in which it is applied. Energy democracy not only highlights the need to democratise energy production, transmission and consumption, but also the need for the redistribution of political power through resisting, restructuring, and/or reclaiming energy systems [4-9].

By transforming how energy is managed and controlled, local renewable energy initiatives are supported, the control of power services by local government and the shared ownership models are promoted. These efforts strive for increased community involvement, transparency, and fair distribution of energy transition benefits like accessible energy and job opportunities in renewable sectors [10, 11].

The European energy sector has experienced unpresented changes [12], the COVID-19 pandemic and Russia's 2022 invasion of Ukraine, both of which highlighted the need for energy independence [13]. In response, the European Union (EU) developed the REPowerEU plan [14], which focuses on diversifying gas suppliers and reducing faster the use of fossil fuels in our homes, buildings, industry and power system, by increasing energy efficiency gains, expanding renewable energy use, and managing electricity demand. This plan aligns with European Union's broader goal for a sustainable energy future, as outlined in the European Green Deal [15] and the Fit-for-55 package [16].

The goal, regarding the energy sector, is to create social, technological and business innovations to turn inactive consumers into Energy Activated Citizens and creating Data-Driven Energy-Secure Communities engaged in demand response programs or even larger-scale Renewable Energy Valleys [17-18]. In addition, it is crucial for society to actively participate in the socio-energy transition where ownership of action and infrastructure to effectively address cost, security, and environmental issues are promoted. Collective energy actions are pivotal for promoting the uptake of renewable energy and placing citizens at the core of the energy transition [19]. Addressing energy poverty is also crucial for a just transition that enhances energy democracy [20]. By democratising energy, shifting from centralised to decentralised production and creating energy communities, we seek to ensure that energy transition is inclusive, sustainable, and "leave no one behind" [21], as presented in "Figure 1".

The Horizon Europe project, ENPOWER (https://enpower-project.eu), aims to transform the energy sector and turn traditional passive energy citizens into active ones by implementing a set of tools and services to increase the engagement in energy community. This includes, developing a Social Science Framework for engaging consumers and prosumers in the energy transition and supporting them throughout the process of creating, constituting and developing an energy community. It also includes, developing an Energy Data Space [22] compliant digital backbone for consumer and community-level data-driven 'activation', and interoperable automated privacy and sovereignty-preserving Demand Response (DR). In addition, providing Individual and aggregated data-driven consumer engagement activation, planning and facilitation tools and services, as well as closed-loop optimisation services for consumers activation management [23-26]; eventually managed in automated way via interoperable DR. Finally, designing new market roles, as well as sharing economy business models.

The rest of the paper is structured as follows: Section 2 presents the "state-of-play" on energy and policy EU packages including energy communities, Section 3 describes the ENPOWER project approach, Section 4 presents the pilot cases where the ENPOWER will be tested and last is the Conclusions section.

II. State of play

The Clean Energy for All Europeans Package [27] establishes the legal framework for the EU's energy transition and it is essential to the policy landscape of the EU. The package includes actions aimed at promoting renewable energy, energy efficiency, and the idea of energy solidarity amongst Member States. Through this package, energy communities have been officially introduced into the European legislation [28-29], with the aim to give more options to people for producing and sharing renewable energy. This paves the way for a shift from centralised to decentralised energy systems, where people can choose and share their energy sources. Within this framework, the EU recognises two distinct types of energy communities: the Citizen Energy Community (CEC) and the Renewable Energy Community (REC). CECs, as described in the revised Internal Electricity Market Directive (EU) 2019/944 [30], are designed to benefit their members or local areas by adding a social dimension to energy projects, whereas RECs, as described in the Renewable Energy Directive (EU) 2018/2001 [31], they focus geographical (shareholders or members of RECs must be located in the proximity of the renewable energy projects that are owned and developed by the REC) and they enhance the connection between the community and the local energy source.

Both types of communities, at many stages of the energy value chain (generation, consumption, distribution, storage, and electric mobility), enable collaboration among citizens, local authorities, small and medium-sized enterprises (SMEs), and municipalities. Despite its similarities, such as voluntary involvement and a desire for shared goals, CECs prioritise social advantages for their members or local regions, whereas RECs are distinguished by their local geographical connections.

The EU legislation (RED II (Art. 22 and IEMD Art. 16)) [29-30] outlines many requirements for increasing citizen engagement. EU regulation demands that energy community is based on open, voluntary participation of citizens, small and medium-sized businesses, and local governments. Energy communities should be based on democratic principles, with members sharing control and decision-making with the ultimate goal of providing social, environmental, or economic advantages to the local community. Member States must analyse the hurdles to RECs' development and the possibility for them to compete with other market participants, as well as provide an enabling framework for RECs. RED II also requires Member States to ensure that end users, in particular household consumers, have the right to participate in a renewable energy community, provided that their participation does not constitute their primary commercial or professional activity [33].

Russia's invasion of Ukraine has forced the European Union to initiate a complete transformation of its energy and climate policies, with the goal of transitioning away from dependency on Russian natural gas. Among many other concerns, the conflict has brought to light two crucial characteristics. To begin, natural gas remains critical for large European companies, therefore investment in infrastructure for this energy source must be revitalised and its supply diversified through new agreements with more countries [32]. Second, the development of renewable energies is not progressing as predicted, as Europe is unable to replace its hydrocarbon use with renewable energies and gasses in the short and medium term.

The REPowerEU Plan, issued in May 2022 [14], is the energy package that addresses the main challenges of adapting the EU's energy and climate policy to the new global energy context brought about by Russia's invasion in Ukraine. It has designed a strategy around four key ideas:

- Saving energy.
- Diversifying supplies.
- Rapidly replacing fossil fuels by accelerating the transition to clean energy.
- Intelligently combining investments and reforms.

The deployment of the REPowerEU Plan is leading to a profound reform of the regulatory framework for the energy sector in the EU, which is currently underway and focused on two main issues. On the one hand, a large proportion of the measures adopted from the REPowerEU Plan are related to the repositioning of natural gas in energy and climate policy.

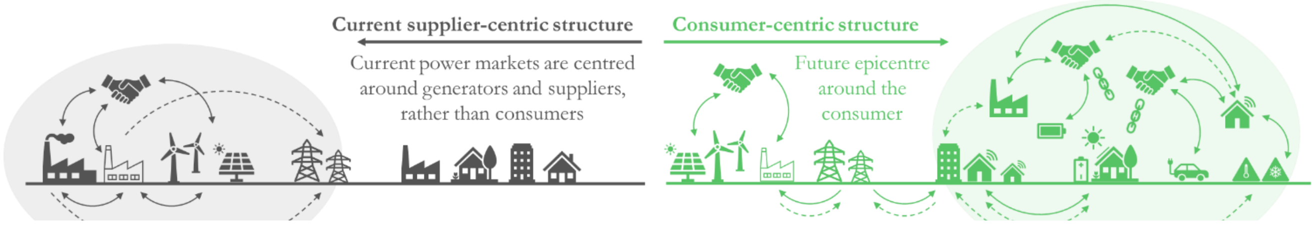

Figure 1:ENPOWER paradigm shift to focus on the consumer.

On the other hand, another set of measures relates to an acceleration of the energy transition through the massive implementation of renewable energies, the incentive to new climate technologies, and the promotion of renewable gases [34].

III. The ENPOWER approach

The current landscape presents several challenges hindering the scaling up and replication of energy citizenship practices. Social practices, technology adoption, and organisational/business models lack maturity, impeding seamless access to energy and flexibility markets for consumers. The financial and non-financial benefits of energy communities remain unclear, affecting the latter's integration into the energy system. To address these challenges, digital transformation emerges as a key enabler, aligning with the proposed 'Action Plan on the Digitalisation of the Energy Sector' [35]. However, the wide-scale deployment of Renewable Energy Sources (RES) and the emergence of energy-activated citizens pose significant challenges to the electricity market, necessitating a shift towards a more consumer-centric structure, "Figure 2" [36-37].

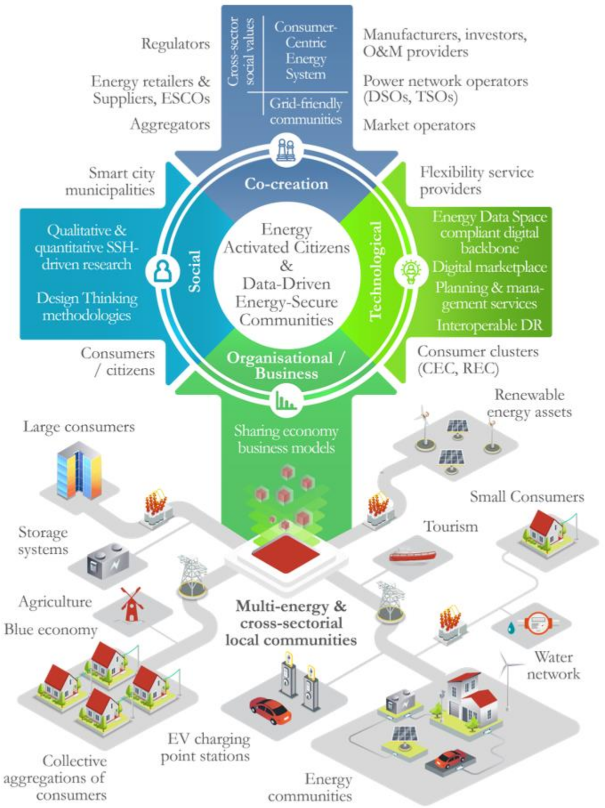

Figure 2: The ENPOWER Vision.

Three dimensions outline the challenges faced in deploying a consumer-centric European energy system. Firstly, the social dimension highlights the need for enhanced energy literacy among citizens to understand energy market dynamics and benefits. Effective tools and methodologies driven by Social Sciences and Humanities (SSH) can empower consumers to participate actively in the energy transition [38]. Additionally, the lack of suitable incentive mechanisms inhibits the unleashing of flexibility potential, calling for innovative incentives that combine financial and non-financial dimensions to encourage active participation [39].

Secondly, the technological dimension underscores the absence of digital tools and frameworks for setting up, planning, and scaling energy communities [40]. There is a crucial need for innovative tools to assess community readiness, size, and implications on non-community members. Furthermore, fostering a culture of energy data sharing is essential to support consumer activation and participation, thereby enhancing trust and transparency in the energy system.

Lastly, the business dimension presents challenges in adopting sharing economy and social innovation-based business models. The absence of such models impedes shared ownership of renewable energy assets and equitable distribution of benefits among community members. Regulatory and market frameworks must evolve to integrate new actors efficiently and deliver value to all customers. Collective aggregation of consumers as an intermediate layer among energy stakeholders could enhance system-level benefits and facilitate the transition towards a decentralised energy system [41-42].

The ENPOWER project, employs a comprehensive methodology, integrating social, technological, and business aspects to revolutionise the energy systems and empower communities "Figure 3". At its core, ENPOWER seeks to create a consumer-centric and socially responsible energy landscape.

Consumer groups are mobilised and engaged by offering personalised cluster-level multidimensional incentives to actively participate as flexible consumers. This engagement facilitates optimal management of renewable energy systems, enabling access to electricity markets with clean energy flows [43]. Additionally, new business models for flexibility are promoted, ranging from local Peer-to-Peer (P2P) markets to wholesale marketplaces, focusing on engaging households and SMEs through citizen energy communities.

The project unfolds across three distinct phases, each contributing to a full development cycle. The first phase, Specification & Technologies adaptation, involves market analysis, designing business models, defining scenarios, and setting system requirements. Insights for ENPOWER's development are derived from engaging with consumers, analysing pilots, and related research, culminating in a Business Sandbox. In the second phase, Product Integration & Fine Tuning, feedback refines business models and requirements, leading to the deployment of advanced functionalities and pilot testing. The final phase, Product Assessment & Market Uptake, focuses on consolidating technologies, enhancing scalability, and assessing business benefits through pilot validations, ensuring readiness for market introduction.

ENPOWER framework will be validated along 4 pilot energy communities (Front Runners) and further replicated in 2 others (Early Adopters), covering different levels of maturity of communities, to demonstrate increased RES local self-consumption and consumers participation to the energy markets, while nurturing increased local security of supply. Demonstration activities by Front Runners are supported by relevant technology enablers and business assessment, following a three-loop cycle structure across pilot cycles. Moreover, Early Adopters in Spain and Hungary commit to

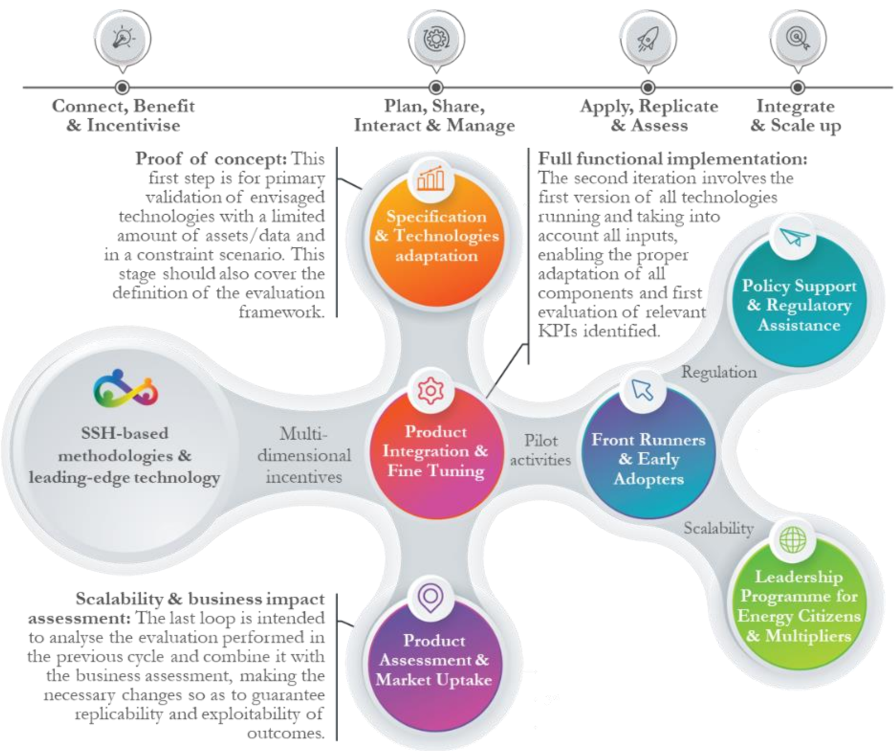

Figure 3: Business Assessment & Evaluation.

using pilot-tested technologies and outcomes to refine development processes and define new business models.

Regulatory assistance accompanies project actions from specification and technologies adaptation to product assessment and market uptake phases. Additionally, ENPOWER designs and implements a capacity building program for regional/local authorities and energy communities to benefit directly from peer experiences and lessons learned in organising and running energy communities.

ENPOWER is not the only project that aspires to address the above challenges. InterConnect [44] is a European project focusing on the digitalisation of the electricity sector using Internet of Things (IoT) architectures integrated with Artificial intelligence (AI), blockchain, cloud computing, and big data to ensure interoperability between equipment, systems and privacy/cybersecurity of user data. BD4NRG project [45] aims to create a decentralised, data-driven energy ecosystem utilising big data analytics, blockchain, and AI to improve operational performance across energy sector stakeholders. Furthermore, BRIGHT [46] leverages a participatory co-creation process to explore demand response opportunities in residential sectors affected by immature technologies and regulatory challenges, aiming to establish a flexible consumption framework across multiple community layers. One other project is IANOS [47], which focuses on optimising island energy systems through a virtual power plant that integrates AI for balancing energy supply and demand. This initiative enhances local energy management and supports island stakeholders in developing renewable energy strategies, utilising advanced tools like crowd equity platforms and life cycle assessment toolkits to facilitate sustainable investments and energy system planning.

IV. Testing the Approach

The services that have been identified for the development and assessment are the result of a thorough examination of pilot capabilities, which considered the services' distinct business models, current infrastructure, geographic reach, and growth potential.

ENPOWER incorporates several innovative tools and services to increase energy efficiency and engagement. For example, AI-based consumers clustering and market segmentation algorithms. The Energy community planning tool will enable consumers to increase their own awareness and readiness to make informed choices about energy practices, behaviours and actions, such as the situated identification and selection of small greener energy producers, against increased energy efficiency, improved decarbonisation of the energy system, reduction of energy bill, alleviation of energy poverty. Also tailored to the energy stakeholders, to combine the available and the planned renewable generation and flexible load assets with energy consumption/presumption profiling to determine potential optimal dynamic sizing of the energy community, while looking at the benefits for local community members and the impact on the overall energy system.

Moreover, within ENPOWER, services for optimal energy management across commodities, aimed at maximising self-consumption for individuals and communities will be deployed and cross-sector digital twins for modelling and planning will be utilised, focusing on heat and e-mobility based flexibility modelling [48]. It also introduces a top-down, bottom-up hybrid Virtual Power Plant (VPP) for cross-commodity flexibility optimisation, which uses dynamically created coalitions to match top-down static consumer portfolios and respective consumer clustering against on-the-fly aggregated energy-related financial and non-financial preferences from coalition members as subsets of energy community members.

Furthermore, closed loop near real time nudging services will be deployed, which provide near real time information on the renewable energy suppliers. These services include a) a Nudging app for near real-time closed-loop targeted information provisioning to the end consumer, such as information of the most convenient energy offering by given subsets of renewable energy producers, b) an Energy Efficiency Management where near real-time information is conveyed to the energy consumer on the consumed energy at disaggregated level (es. smart home appliance level), on the effective share of self-generated consumed energy, or on the share of self-generated energy shared with the community members, as well as providing tips on how to increase share of self-consumption, while achieving energy saving and/or how to match its own energy and social preferences against participation in DR campaigns and c) a Vehicle to Grid (V2G)-based flexibility management for providing incentives to communities of Electric Vehicle (EV) drivers (e.g. to discharge their vehicle to support the grid and earn rewards), allowing the energy community to meet sudden power demands while also ensuring grid stability.

The above tools and services will be provided in an open and interoperable manner by leveraging on Energy Data Space to support consumer and community-level data-driven electricity-centred "activation" and automated management of the activation and on Digital DLT/blockchain/smart contracts near real time marketplace to allow information and energy and other non-energy tangible and intangible assets sharing, trading and reciprocal compensation, ranging from energy demand and supply matching among consumers and prosumers, energy consumption data energy assets.

The tools and services will be deployed, evaluated, authenticated, and scaled in the pilot programmes using a two-pronged technique. By capitalising on the opportunity to introduce multiple services to each pilot, each one will be designated to a Front Runner pilot (Austria, Portugal, Greece, and Ireland), succeeded by Early Adopter pilots (Hungary and Spain). With this methodology, the replicability potential of ENPOWER solutions is maximised by utilising the infrastructure and technical resources of the pilots to develop and evaluate services across many locations.

A. Austria

An Austrian partner is operating a P2P marketplace with a unique accounting and billing system for matching RES electricity generated by its members with consumers. The main challenge is to use the recently established regulation for energy communities in Austria (RECs and CECs), in order to grow substantially as a cooperative synergy enabler and service provider for a cascading scheme of communities (e.g. collective investment and sharing of all types of RES capacity, energy savings, and data aggregation services).

The Austria pilot case involves the Energiegemeinschaft (Regional Energy Community) Dreißgen-Spörbichl (REC DS) in Mühlviertel, Upper Austria. The goal is to integrate more photovoltaic (PV) systems and expand the number of participants. Real-time power data will engage participants via a web interface and mobile app. The Energy community planning tool will assess benefits and recommend automated control systems and storage. The pilot will also create flexibility market mechanisms with financial incentives for flexibility owners, encouraging future collaboration.

B. Portugal

Portugal has a long history of energy cooperatives; however, the legislative framework is currently being established in communities. Regarding the Portuguese pilot, the challenges include integrating investments in RECs and enhancing collective renewable energy self-consumption by independent prosumers. Efforts are also focused on optimizing self-consumption within low voltage grids, aligning organisational models with the CEC framework, and creating synergies with e-mobility initiatives. Additionally, there is a need to engage citizens as active, flexible participants in the national energy market and to develop new business models that effectively manage and monetise surplus energy from photovoltaic self-consumption [49].

Portuguese pilot's goal is the demonstration and evaluation of different community models, emphasising on collective RES self-consumption, REC and Local Energy Community (LEC), utilising existing business models, infrastructures, and platforms. It will explore different configurations of local RES and individual and collective consumption patterns. The pilot will make use of demand and generation data from metering to assess the impact of energy services on improving energy resilience and to enable the provision of non-energy services such as maintenance and asset replacement. It will also examine the integration of e-mobility and charging infrastructure in energy communities, evaluating collective usage and the potential supply of charging services to people outside the community. Moreover, aggregation will be used to effectively manage RES surplus from all prosumer participants [50]. An optimised balancing mechanism of energy flows will be provided, allocating energy among all energy community participants to increase the use of local resources. P2P sharing of local RES electricity within communities will be examined to compare the benefits to alternative options like aggregation for sale in electricity markets. Further assessments will identify the community members' potential flexibility using casual models, indicating their reactions to different types of incentives, leading to targeted programs with consumer-specific incentives to increase participation in flexibility services.

C. Greece

The Chalki island, in the southeastern Aegean, near Rhodes, is powered mainly by diesel generators installed on its larger neighbour island. the role of citizens needs to be gradually evolved from consumers to prosumers by steadily turning the island into 100% green, sustainable and autonomous destination.

The Greek pilot aims to showcase how aggregated flexibility from prosumers and smart active consumers, organised in a local community and supported by an independent aggregator, can offer services to the grid network operator to address distribution grid congestion issues. It focuses on optimizing flexibility management of the island's assets, particularly during the summer tourist season, by utilising flexibility from air conditioning/heat pumps in residential and tourist accommodations, e-mobility (including EVs and e-boat smart charging with vehicle-to-grid storage), and smart water pumping. Smart EV charging and V2G features can reduce renewable energy curtailment, boosting the island's self-sufficiency. Household consumption behaviours will be influenced through demand response mechanisms, particularly for air conditioning/heat pumps during the summer. The pilot aims to encourage agile grid management by aligning household consumption with high renewable energy production intervals. Water management will also be improved in collaboration with the water network operator. A local flexibility hybrid VPP, will facilitate trading of flexibility among providers and consumers, including exchanges with energy and non-energy assets like social services for vulnerable populations.

D. Ireland

Rural regions like the Dingle peninsula pose a particular challenge to grid operators/planners, on both social and technical levels (e.g. engagement of citizens, technology integration on the grid edge complex particularly in Dingle with significant congestion issues on the MV network) Trials for flexibility services for the distribution network to manage increasing electrification are currently being designed and implemented.

The Irish pilot focuses on three main activities across residential, agricultural, and transport sectors to enhance local energy system flexibility and community resilience. Firstly, it aims to involve farmers in the energy transition to boost renewable generation capacity and reduce costs and emissions. Secondly, data-driven approaches will improve community self-sufficiency by analysing energy consumption and generation to design effective services and engagement strategies. Lastly, a Citizen Renewable Platform will help schedule local resources based on forecasts and prepare for disruptive events like extreme weather, ultimately promoting citizen participation in decarbonisation efforts and grid resilience.

E. Hungary

Békéscsaba municipality (BCS) focuses on decarbonisation with a complex energy program (‘Smart Microgrid Phase I-II’). BCS has installed energy infrastructure to promote local energy generation and consumption. The smart meter rollout in Békescsaba city is continuous and shall be the first Hungarian city with a full electricity smart meter rollout. As a next phase, the municipality went through the planning process to install more energy generation, storage, and distribution assets. The next phase will involve local municipality buildings, industrial complexes and citizens as part of an energy community. However, the concept of energy communities with consumer engagement is relatively new in Hungary and even though there have been some initiatives to create such communities recently, these are still under preparation.

The Hungarian pilot aims to establish an energy community and boost community involvement in Békéscsaba. The Austrian pilot will provide expertise on social engagement and citizen involvement, while Békéscsaba will utilise their P2P marketplace and Nudging app. Additionally, selected solutions from the Chalki island pilot will be replicated in Békéscsaba.

F. Spain

Distribution System Operators (DSO) are pivotal to the energy transition since they handle the flexibility resources of several aggregators (batteries, EV charging stations), large prosumers and residential prosumers. A coordination of all flexibility resources from the perspective of the local distribution network should be achieved and provide the DSO with appropriate tools to monitor the deployment of flexibility resources installed by different actors.

The Spanish pilot will explore the role of a small DSO as an Energy Community Developer in Fornes, a village in Granada with over 300 residents. There is going to be a collaboration with the town council to establish a Green Community in Fornes, installing small PV plants at each public supply point to share energy among participants. There is going to be an employment of energy community planning and gamification activities to engage prosumers. Data-driven services tested in previous pilots will also be implemented.

G. Project’s challenges

ENPOWER is an ambitious project and it reasonable to assume that some risks and challenges might arise. Since one of the of the main goals of the project is to turn the passive energy citizens into active ones, low engagement of energy citizens and stakeholders from the energy value chain during the co-creation process, reluctance and lack of motivation of stakeholders to data sharing and reuse are significant risks. Another challenge is the replication of solutions across different geographies, which may not meet expectations. Additionally, the energy communities in Hungarian and Spanish pilots have not yet been established, and bureaucracy, legal issues and other factors might cause delays. Despite these and a few more challenges that the project has identified, risk management strategies were developed to address them.

V. CONCLUSIONS

In conclusion, a shift to 100% renewable energy without addressing social justice risks concentrating power in the hands of a few huge firms, keeping global disparities. Ensuring inclusion and equity is critical in this shift. Through energy communities, citizens are in the centre of the transition from centralised to decentralised energy systems.

Enhanced engagement, however, is only one aspect of this challenge. Active societal participation in the socio-energy transition is equally important and thus it is essential to provide the necessary tools integrated with insights from social sciences, state-of-art technologies and innovative business models. By ensuring that energy communities have access to tools and services tailored to their needs, we can turn traditional passive energy citizens into active ones and also transform energy consumers / communities into digitally enhanced and grid-friendly ones.

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