Stakeholders analysis: KPIs, Scenarios and Use Case definition

D2.2

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Deliverable

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TWINERGY	**957736**	**Intelligent interconnection of prosumers in positive energy communities with twins of things for digital energy markets**

DELIVERABLE REFERENCE NUMBER AND TITLE

D2.2

Stakeholders analysis: KPIs, Scenarios and Use Case definition

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Version History

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v0.2	31.03.2021	UNL Team, with the help of ETRA	UNL/ ETRA	Detailed Revision of the Use Cases, following Task 4.4 requirements
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Statement of Originality

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Executive Summary

The purpose of this document is to provide an overview of the stakeholders' requirements analysis of TwinERGY, a project funded by the HORIZON 2020 Programme of the European Commission under the Grant Agreement No. 957736. This report comprises the requirements and KPIs of stakeholders in diverse environments of the TwinERGY project and presents a strategy for the implementation of best practices to ensure the maximization of consumer engagement in a revamped energy market. Use Cases (UCs) and scenarios have been developed as part of this task, translating high-level policy goals of the EU into tangible and measurable impacts to stakeholders. Thereby, this report acts as a foundation for the whole project, and especially the pilot studies in WP9, ensuring that stakeholders' needs, and requirements are taken into account and drive decisions for the TwinERGY Project.

A fundamental project objective is to examine new ideas and explore model scenarios in real-time, so as to improve demand response without affecting physical processes or interrupting the daily schedules and operations of consumers. The stakeholders need to be involved in every step of the process, and that is why it is paramount to first determine who they are, and what key performance indicators (KPIs) are to be analyzed and measured.

Task objective

The scope of the task T2.2 – "Stakeholders Requirements" is to identify the requirements of stakeholders in diverse environments and develop a strategy on how to implement different best practices according to the special characteristics of the areas of interest in order to achieve the maximization of consumer engagement in an energy market with high penetration of Renewable Energy Systems (RES), Demand Response programs, energy storage and electric vehicles (EVs). This task involves the Use Cases (UCs) and scenario development as well as the methodical decomposition of high-level requirements to specific Tasks, in order to identify and analyze underlying risks. The results derived from this analysis will form the foundation upon which the pilot demonstrations will be implemented in WP9. In order to evaluate the results of the solutions proposed and implemented within TwinERGY, it is necessary to quantify the tangible and measurable impacts which contribute to specific EU policy goals. To this end, meaningful, understandable, and quantifiable KPIs will be established and followed according to the identified needs of the UCs.

Approach

The stakeholder requirements analysis is based on a thorough literature review of related studies, as well as insights from stakeholders through a focus group whereby Use Cases and scenarios were developed. The respective Use Cases and scenarios were reviewed in interviews with support partners, experts, and consumers. Based on this qualitative research approach, the high-level policy goals were transformed into more easily understandable and quantifiable KPIs, which directly contribute to the EU policy related to the TwinERGY project. The following Figure 1 illustrates an overview of all steps covered within this task (see section 1.2 for methods):

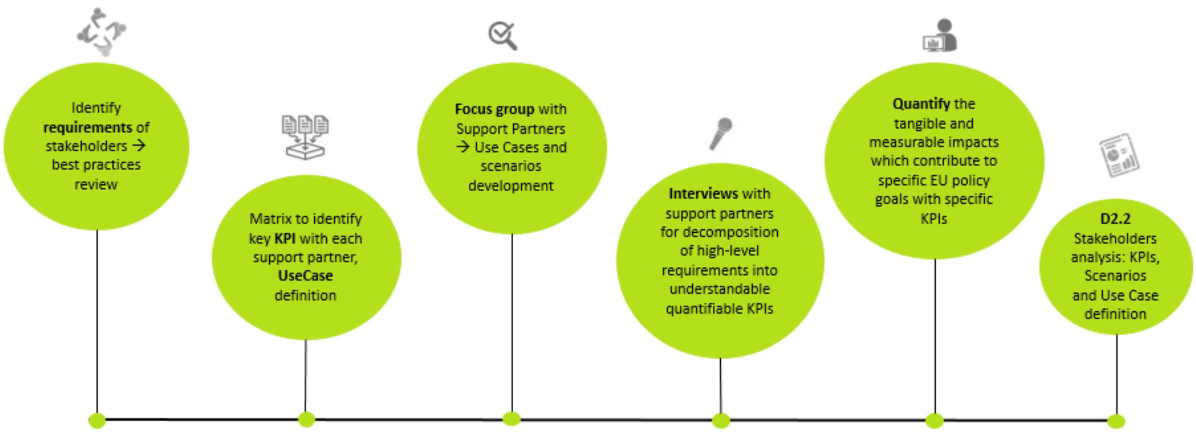

Figure 1: Stakeholders Requirements Analysis in D2.2

The specific methods applied in all these points are discussed in section 1.2.

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List of abbreviations

ARERA	Italian Regulatory Authority for Energy, Networks, And Environment
DERs	Distributed Energy Resources
DNO	Distribution Network Operator
DSM	Demand-Side Management
DSOs	Distribution System Operators
ESCOs	Energy Service Companies
EVs	Electric Vehicles
HARB	Hypergraph-Based Adaptive Consortium Blockchain Framework
ISO	Independent System Operator
JRC	European Commission's Joint Research Center
KPIs	Key Performance Indicators
LECs	Local Energy Communities
LEM	*Local Energy Market*
LV	Low-Voltage
MV	Medium-Voltage
Ofgem	Office Of Gas and Electricity Markets
PPB	Private Permissioned Blockchain
PUCs	Primary Use Cases
RAE	Regulatory Authority for Energy
RES	Renewable Energy Systems
SUCs	Secondary Use Cases
TE	*Transactive Energy*
TEM	*Transactive Energy Module*
TSOs	Transmission System Operators
UCs	Use Cases
V2G	Vehicle-To-Grid
VPP	Virtual Power Plant Operator

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1/ Stakeholder Analysis

1.1 Background

The term "stakeholder" was most prominently defined by Freeman (1984) as "those who affect or are affected by a decision or action" in the context of project management. Literature on project management thereby recognises that stakeholders are important for the success of any project because of their 1) possible contributions, 2) assessment of project success, 3) possible resistance causing risks and hinder project success, and 4) positive and negative effects on it (Eskerod, Huemann & Savage, 2015). Due to the importance of considering stakeholders throughout the project, a thorough stakeholder analysis must first be conducted. This analysis serves to determine who is affected by the innovations of the TwinERGY project or could influence the outcomes of the project one way or another. Stakeholders can be individuals or organizations, and the goal behind a stakeholders' analysis is mainly to uncover their interests and intentions and define what will impact the project's implementation (Varvasovszky, 2000). Moreover, the analysis aims to create synergies among different stakeholders and take proactive measures to resolve potential friction and ensure the project's success.

1.2 Method

The following graphic (Figure 2) illustrates the five-step approach that the current analysis will follow to identify the TwinERGY project's requirements. This approach was developed based on reviews of stakeholder analysis recorded in the literature, which was adapted to match the deliveries of this work package.

Figure 2: The Five-step Approach

The specific methods adopted throughout these five steps will be presented in the subsequent sections. Moreover, as displayed in Figure 2, the interviews that were conducted delivered insights to the majority of the steps to enrich the research of literature and past projects with insights from primary sources.

It should be noted that this task 2.2 – "Stakeholder Requirements" is focused on the first, descriptive part of the stakeholder analysis. However, the TwinERGY project will go beyond these descriptive methods adapting a normative approach by actively involving stakeholders at later stages of the project (namely in; T4.2, T5.4, T6.1, and throughout WP9).

1.2.1 IDENTIFICATION AND CLASSIFICATION OF STAKEHOLDERS

First, a preliminary list of stakeholders involved in the TwinERGY project was identified to understand the current situation. Reed et al. (2009) noted that while this is often done on an ad-hoc basis, the stakeholder identification should be developed through a systematic process to avoid disregarding any potentially important stakeholder and ensure that the selected group provides statistically unbiased analysis. Therefore, initially, a thorough review of secondary sources such as published documents, reports, and policy statements referring to the different stakeholders within the energy sector and similar projects was conducted.

The classification of stakeholders was structured into four broad groups of stakeholders, namely: *End Users, System Operators, Authorities,* and *Retail & Energy Services*. These categories were defined based on an analysis of previous reports and projects regarding the energy sector that fall under the Horizon 2020 umbrella.

1.2.2 ANALYSIS OF STAKEHOLDERS

In order to get a thorough analysis of the positions and behavior of the different stakeholders towards the TwinERGY implementation, the four stakeholder groups and relevant distinct sub-groups were analyzed based on prior literature on the energy sector and outcomes of similar projects. As a result of this analysis, an introduction of the broad stakeholder groups is provided. Moreover, past research on similar initiatives and projects was reviewed to identify stakeholder groups benefits and barriers associated with implementing the TwinERGY Project.

Afterwards, these findings were enriched through a collection of information from primary sources through semi-structured interviews and focus groups with representatives of stakeholder groups, in which were included stakeholders from various regions, nominated by project partners. These qualitative methods provided first-hand in-depth insights to better understand the various and distinctive requirements of the diverse stakeholder groups.

Moreover, the interviews and focus groups and the stakeholder types were analyzed based on different mapping dimensions. Table 1 summarizes the most used dimensions recommended for stakeholder analyzes in prior literature.

Table 1: Literature review of Mapping dimensions

Mapping Dimensions	Authors
Power/Influence dominance – Legitimacy – Responsibility	Fassin (2009)
Value Hierarchies & Key Performance Areas	Fletcher et al. (2003)
Power – Interest	Mendelow (1991), Kamann (2007)
Power – Legitimacy – Urgency	Mitchell et al. (1997)
Power – Interest – Attitude	Murray-Webster & Simon (2006)
Potential Threat vs. Potential Cooperation	Savage et al. (1991)

Based on this literature analysis, as well as a thorough review of similar projects, these mapping dimensions were compared to one-another, so as to choose the best fit for the TwinERGY project. In order to get a complete inquiry of the stakeholders, a three-dimensional stakeholder mapping strategy was favoured. Out of these, Mitchell et al., (1997) and Murray-Webster & Simon (2006) strategies, were the most commonly adapted in past projects. However, while Mitchell et al., (1997) are more focused on organizational stakeholders, Murray-Webster & Simon (2006) mapping was developed specifically for the management of projects with change initiatives. Due to this fact and the corresponding nature of the TwinERGY project of initiating change in the energy market, Murray-Webster and Simon's (2006) proposed stakeholder analyzes framework along the dimensions of *Power – Interest – Attitude* grid was chosen. The three-dimensional framework for stakeholder mapping is based on the following dimensions:

1. **Power** – this dimension represents the stakeholders' capability to influence the TwinERGY project outcomes. This influence may be impacted by their positional or resource power in the energy industry or their expertise and credibility in the subject matter. This dimension is measured qualitatively, being either *present/powerful* or *absent/ insignificant*.
2. **Interest** – this dimension is related to the implementation of the TwinERGY project. It measures the stakeholders' involvement in the project, either active or passive (Murray-Webster & Simon, 2006). Also, their motivation, needs, and strategies concerning the project are considered. Interest is qualitatively assessed and can only be *yes/active* or *no/passive*. It must be noted that interest is not the same as support; it may also be defined as adverse interest. Thus, the attitude dimension is necessary to assess the stakeholders' about the project.

3. **Attitude** – this dimension focuses on the effects that the implementation of it may have on their existing business model or the nature of the stakeholder. It is measured by the extent to which they "*back*" *(support)* or "*block*" *(resist)* the project (Murray-Webster & Simon, 2006)

It should be noted that the assessment of all these dimensions is subjective and thus dependent on the person scoring them. Moreover, they are all assessed qualitatively, and scores might evolve over time.

1.2.3 STAKEHOLDER REQUIREMENTS (KPI ORGANIZATION)

One of the main targets of this task is to develop meaningful, understandable and quantifiable Key Performance Indicators (KPIs). To achieve this objective, first, the TwinERGY proposal was thoroughly analyzed in order to attain the most relevant KPIs for stakeholders, Use Cases (UCs), and the pilot demonstrations. The analysis resulted in a comprehensive list of KPIs and sub-KPIs. The conduction of interviews with focus groups aimed to verify these findings by utilizing inputs from primary sources.

1.2.4 STAKEHOLDER – KPI MATRIX

As an overview of the relevance of each stakeholder group for the success of all of the KPIs, a Stakeholder – KPI Matrix was developed taking into account the preceding summary of KPIs. The involvement of each stakeholder group, for each of the sub-KPIs, was scored based on the following matrix (Figure 3), which had been adapted based on the work of Newcombe (2003).

Figure 3: Stakeholder Involvement matrix

This two-dimensional matrix allows the stakeholders categorization based on their *Power* and *Attention* to each specific KPI. According to the resulting classification, their involvement in the success of that KPI is analyzed.

1.2.5 STAKEHOLDER MAPPING

Based on the preceding analysis of the stakeholders throughout the three dimensions (*Power-Interest-Attitude)* different combinations of scores, so-called typologies arose. In this section, the stakeholders typologies are presented on Figure 4 "*Power – Interest – Attitude* Venn diagram". This provides important insights on the importance of the stakeholders for a successful implementation of the TwinERGY project. Thus, these findings should be used on the future as a reference when engaging stakeholders.

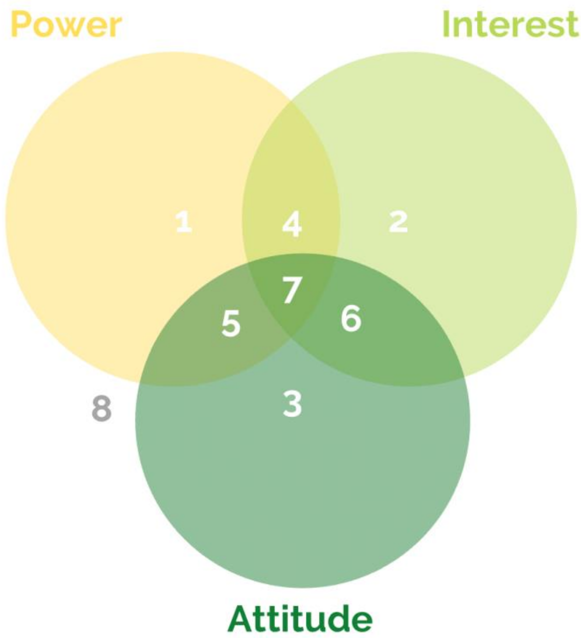

Figure 4: Power - Interest - Attitude Venn diagram

1. **High Power Stakeholders** – *powerful, passive, blocking*. This is a significant group of stakeholders that must be understood and considered in order not to hinder the project implementation.
2. **High Interest Stakeholders** – *insignificant, active, blocking*. These should be considered and engaged and then can be marginalized.
3. **Positive Attitude Stakeholders** – *insignificant, passive, backing*. This stakeholder group should be kept informed about the project and communicated with, but they are not a priority.
4. **High Power & High Interest Stakeholders –** *significant, active, blocking*. Need to be engaged to disengage; the TwinERGY project team should be aware of their actions since they might be dangerous.

5. **High Power & Positive Attitude Stakeholders –** *powerful, passive, backing*. This stakeholder group is important and should be engaged to activate their interest and possibly turn them into one of the most important stakeholder groups.
6. **High Interest & Positive Attitude Stakeholders –** *insignificant, active, backing*. These stakeholders can support the project implementation, and thus should be informed about the process and cooperated with.
7. **Most Important Stakeholders –** *powerful, active, backing*. Since this group belongs to all three dimensions, they are the most important stakeholders of the project, and thus everything should be done to keep them satisfied. Close attention must be paid to their requirements.
8. **Non-Stakeholders –** *insignificant, passive, blocking*. If a stakeholder group does not score positive in any of the three dimensions, they are non-relevant stakeholders who do not necessarily have to be considered for the implementation of the project.

2/ TwinERGY Stakeholders Identification

In this project, four broad groups of stakeholders of the TwinERGY project are considered (Figure 5), namely:

1. ***End Users***
    - Residential consumers (prosumers)
    - Commercial users
    - Industrial users
    - Distributed energy resources (DERs)
2. ***System Operators***
    - Distribution system operators (DSOs)
    - Transmission system operators (TSOs)
3. ***Authorities***
    - Policy-makers
    - Regulators
4. ***Retail and Energy Services***
    - Aggregators (retailers and local energy communities (LECs))
    - Energy service companies (ESCOs) (not-for-profit and for-profit)

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End Users	• Residential Consumers (prosumers) • Commercial Users • Industrial Users • Distributed Energy Resources (DERs)
System Operators	• Distribution System Operators (DSOs) • Transmission System Operators (TSOs)
Autho-rities	• Policy Makers • Regulators
Energy Services	• Aggregators (Retailers and LECs) • Energy service companies (ESCOs)

Figure 5: Stakeholder identification

Each of these stakeholder groups is introduced in the following pages, and their KPIs concerning the TwinERGY project are presented.

2.1 End Users

2.1.1 RESIDENTIAL CONSUMERS

Residential consumers play a significant role in total power consumption, with a demand profile that dramatically relies on climatic conditions (Patel, Srinivasan, & Srinivasan, 2016). Residential buildings comprise a considerable source of flexible energy demand and storage, potentially providing distribution and transmission system operators with the needed services to balance demand and supply and manage power quality.

The term prosumer is used for those who both produce and consume electricity. Prosumers can sell any surplus generated by DERs back to the main grid, thus increasing their share of renewable generation (EPRS, 2020). In the present report, the term "prosumer" is used mainly to refer to residential consumers. As stated in the proposal, "TwinERGY will define new business models, respective rules, standardized contracts and technological tools to enable energy retailers and local energy communities to undertake the aggregator role and bid the huge flexibility potential of their prosumers/members **(mainly residential prosumers)** in energy markets".

When DERs connect to the electricity grid, the relationship between the customer and the energy market changes as it becomes more interactive. A study by CE Delft (2016) estimates that 83 % of EU households could become prosumers by 2050. Demand-side management (DSM) schemes can motivate prosumers to refine their energy behaviors by offering them various incentives.

Neves et al. (2020) distinguished consumers and prosumers in their research and developed energy demand profiles that are considered representative profiles of a relevant diversity of family typology, economic and power purchase types of clients within the Portuguese context. The consumer types include working couples without children, working couples with two small children, and working couples with young/adult children.

2.1.2 COMMERCIAL USERS

Within the commercial sector, office buildings and retail structures represent the biggest consumers of energy (Pérez-Lombard, Ortiz & Pout, 2008). Schleich (2009) predicted that commercial buildings have the highest relative potential for energy-savings of 30% through measures such as energy management systems or financing packages that help overcome the barriers to energy efficiency. Recent studies show that commercial users account for half of the peak energy demand (Crosbie, 2016). The International Energy Agency states that "by 2050, the global inventory of flexible assets in the residential, commercial and industrial sectors needs to be ten times higher than it is today" (IEA, 2020).

2.1.3 INDUSTRIAL CONSUMERS

With about 54% of the world's total energy consumption, the industrial sector represents the biggest consumer of energy (EIA, 2016). However, between 2005 and 2017, the European rate of industrial consumption annually dropped at an average rate of 1,3, to 25% of the total energy consumption in 2017 (EEA, 2020). This downward trend has been attributed to the shift towards less-energy-intensive manufacturing industries and the continuing transition to a more service-oriented European economy. However, since 2016, the continuous growth of the EU economy has offset the previous energy-savings, and the final energy use of the industrial sector increased again. Moreover, EU policies such as the Emission Trading System between the industrial and energy production sector have helped drive emissions reduction cost-effectively, with covered emissions decreasing by about 35% between 2005 and 2019 (EU ETS, 2020).

When it comes to the business models within the industrial segment, one can differentiate between **frontrunners** which are large companies, where the cost of electricity represents a large share of their production cost and **laggards** which are smaller companies to whom their consumption of energy plays a relatively minor role. In the past, frontrunners have already adapted to innovations in the energy industry to minimize their energy costs. Laggards, however, see a greater risk related to investments into efficiency gains due to their relatively small energy costs, limited investment budget, and lack of expertise in the matter. The diverging approaches between these two main segments create a vicious dynamic and gap between them, which may lead to the perception that laggards are disregarded in the energy market advancements (InteGrid, 2020).

2.1.4 DISTRIBUTED ENERGY RESOURCES (DERs)

Distributed energy resources (DERs) are small assets with technologies that produce, store and manage energy. Examples include solar panels, small wind turbines, electric vehicles, and microgrids. Greater use of DERs could improve resource efficiency, increase energy system resilience, and give individuals and communities a stronger role in decarbonization. As such, it appears to fit well with the European Green Deal and EU plans for secure, affordable, and clean energy. However, the growth of DERs will disrupt traditional electricity markets and, without proper regulation, their benefits may not be felt equally across society (EPRS, 2020).

Natale and colleagues (2020) developed a methodology to estimate the market potential of DERs connected to a distribution network. The proposed approach can be summarized in the following steps:

1. **Limit the area of interest** that can be one distribution network only, or a group of networks operated by the same DSO, or even an entire territory or region (e.g., a region or a market zone);
2. **Consider or estimate the expected profiles of demand and production** at the PCC at the TSO/DSO interfaces for the area of interest. The expected profiles can arise from historical data or can be forecasted. The consumption curves of passive customers not involved in the service market are also considered. From this perspective, the TSO sees each distribution system at the interface similar to a generator with a four-quadrant capability curve that may import or export energy (reversal flow) from/to the bulk grid;
3. For the DERs involved in offering flexible products, **hypothesize participation profiles in terms of pairs** of price/quantity;
4. **Model the distribution network in terms of topology, lines, conductors**. This step is not necessary for the simulation of the first phase of the extended centralized dispatching model that does not consider the distribution network

operation. This task can be performed according to the procedure described by the researchers Pisano et al. (2019);

5. Assess the quantity that can be offered in the three market models by calculating the effective four-quadrants capability curve of the equivalent generator modeled at step 2.

DERs have given rise to collaborative communities that manage their energy production and consumption load through Peer-to-Peer Decentralised Energy Trading (P2P DET). Karumba and colleagues (2020) propose a Hypergraph-based Adaptive consortium Blockchain framework (HARB), which coordinates DERs through high-order relationships rather than P2P pairwise relationships. HARB is presented in three-layered network architecture to address challenges such as distributed trust in collaborative communities.

2.1.5 RELEVANT KPIs FOR END USERS

- Average energy-savings achieved through Demand Response: 20-25%
- Average Cost Savings through DR: 25-27%
- Reduction of peak demand at levels above 50%
- Regulated comfort and health in built environments at levels above 85%
- End-User acceptance of TwinERGY interventions above 95%
- Prosumer monetary benefits from day one of TwinERGY solution deployment, estimated at €60-80 annually for a typical household, in the form of new revenues.

2.2 Energy System Operators

2.2.1 TRANSMISSION SYSTEM OPERATORS (TSOs)

TSOs are responsible for energy transportation on a national or regional level and as such are a crucial part of the European energy system. The safety and reliability of the power transmission are a priority and thus any imbalances in generation and consumption are a critical concern. They also run the Real-Time Balancing Markets. To effectively balance their systems, they procure flexibility services from neighboring transmission grids or distribution grids (Hadush & Meeus, 2018), although they are not directly involved in the implementation of TwinERGY.

2.2.2 DISTRIBUTION SYSTEM OPERATORS (DSOs)

Traditionally the DSOs are responsible for the maintenance and operation of the distribution grid. However, the massive penetration of DERs at the edge of the grid is changing the nature and role of the DSOs. Their roles are expanding to include connection and disconnection of DER, planning, maintenance, and management of the distribution grid and management of the flexible markets and platforms for local energy markets. As managers of local energy markets, their responsibilities are growing to include actively managing congestion and peak load, moving away from the conventional fit and forget approach (IRENA, 2019; Anaya & Pollitt, 2017).

Currently, solely the TSOs are responsible for the assurance of security of the energy supply; however, once DSOs start developing flexible markets, TSOs will face less certainty on the conditions of future grids (InteGrid, 2020), assuming the proper coordination between the two organizations is put in place. Therefore, for the success of the TwinERGY project and an effective European energy system, close cooperation between the two different types of network operators is required. For this matter, the SmartNet project of the European Commission analyzed and presented potential DSO-TSO coordination methods.

2.2.3 RELEVANT KPIs FOR ENERGY SYSTEM OPERATORS

- Average Cost Savings through DR;
- Reduction of peak demand at levels above 50%;
- Contribution to the avoidance of 217 TWh of RES curtailment in 2050 (according to EU targets);
- Contribution to the achievement of €50B deferred investment for peak generation capacity & transmission and distribution grid reinforcements by 2050;
- Contribution to 1bn tons annual CO_2 emissions reduction by 2050 due to renewables integration.

2.3 Authorities

2.3.1 POLICY-MAKERS

If not managed correctly, DERs may increase the cost of electricity, foster inequality between resource owners and non-owners and increase the uncertainty of managing the grid. Policy-makers have a key role in developing the right regulatory regimes for transitioning the energy system to a decarbonized renewable-based system (EPRS, 2020). Individual policies and policy packages were set in the EU to overcome barriers that obstruct energy efficiency and energy conservation. According to Economidou and colleagues (2020), these policies are sectioned as follows: regulatory, financial and fiscal, information and awareness, qualification, training and quality assurance, market-based, voluntary action, infrastructure investments, and other measures as innovation programs and demonstration projects.

According to Kestner (1991), the "SAVE" directive was the first major policy within the European Union on energy efficiency and conservation. However, since the implementation was not as fast and fruitful as expected, other action plans rose. Geller and colleagues (2006), the 2000 Action Plan was set up to reinforce and accelerate the SAVE directives. Afterward, the 2006 Action Plan set by the European Commission had as a goal to save 20% of the annual energy consumption by 2020 (Backlund, Thollander, Palm, and Ottosson, 2012).

2.3.2 REGULATORS

Previous studies concerning Demand Response have shown that law and regulation drive market changes and accelerate technology advancements (Shen et al., 2014). According to the European Environment Agency, the national regulatory authorities in the energy area for the pilot countries are as follows (Table 2):

Table 2: National regulatory authorities

Country	National Regulatory Authority
Germany	The role of the **Bundesnetzagentur** is to guarantee compliance in the energy sector; low-priced, consumer-friendly, and sustainable electricity supply is ensured. In addition, it acts as a regulatory authority that can impose graded sanctions. www.bundesnetzagentur.de
Greece	The Regulatory Authority for Energy **(RAE)** is an authority that is financially and administratively independent. RAE ensures the confidential collection and processing of information within the energy sector, as well as the approval of retail electricity tariffs. www.rae.gr
Italy	The Italian Regulatory Authority for Energy, Networks, and Environment **(ARERA)** is the independent regulatory body of the energy markets that aim to achieve environmental protection in balancing energy operators' financial objectives with the general public's objectives. www.autorita.energia.it
United Kingdom	The **Ofgem** (Office of Gas and Electricity Markets) is an independent regulatory authority that works with all stakeholders in the energy sector to ensure fair treatment for all consumers. www.ofgem.gov.uk

2.3.3 RELEVANT KPIS FOR AUTHORITIES

- New business models for Local Energy Communities and Retailers: 2 business models (Retailer as an aggregator, LEC as an aggregator)
- Local Energy Communities/ Retailers Acceptance and Satisfaction out of their new business functions (~100%)

2.4 Retail and Energy Services

2.4.1 AGGREGATORS (RETAILERS AND LOCAL ENERGY COMMUNITIES (LECs))

Aggregators have to be able to extract enough value (flexibility) from a pool of resources, to maximize benefits for consumers (and persuade them to hand over control). Firstly, aggregators can optimize energy management (in the case of implicit demand response). Secondly, demand aggregation tackles the market capacity restrictions that cannot be addressed by individual consumers (with a limited nominal power and flexibility capacity).

The European Commission's Joint Research Center (JRC) recently published a report stating that an energy community is "a new form of social movement that allows for more participative and democratic energy processes". Until recently, energy community lacked a clear status in EU and national legislation, taking different forms of legal arrangements (Caramizaru & Uihlein, 2020, p.7). Local energy communities already exist in some European countries, such as Poland, where it balances energy demand and supply at the local level. Local energy management may help decrease costs locally; it can still increase system costs (Caramizaru & Uihlein, 2020, p.34).

The goal of local energy communities is to combine new innovative technologies with locally available natural resources and to raise awareness of energy efficiency and renewable energy usage. The approach is based on the model of the local cycle economy (Local Energy Communities, 2020). However, there have been many barriers identified regarding community energy, which are listed in section 3.5.

2.4.2 ENERGY SERVICE COMPANIES (ESCOs)

According to the European Commission's Joint Research Center (JRC), an energy service company is "a company that offers energy services which may include implementing energy-efficiency projects (and also renewable energy projects) and in many cases on a turn-key basis." ESCOs are supposed to facilitate the financing of operations and ensure lower costs.

A study about the ESCO markets in Europe shows that these entities are seen as "private-sector delivery mechanisms for energy efficiency" (Bertoldi & Boza-Kiss, 2017). The latter authors also provide a barriers/drivers analysis of ESCOs, listed in section 3.5.

2.4.3 RELEVANT KPIs FOR RETAIL AND ENERGY SERVICES

- Two new business models for Local Energy Communities and Aggregators;
- Flexibility trading between energy consumers and aggregators through the delivery of an innovative, open, and transparent Transactive Energy Market infrastructure, based on blockchain infrastructure;
- Local Energy Communities/ Retailers Acceptance and Satisfaction out of their new business functions (~100%).

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2.5 Benefits and barriers of energy-saving programs adoption by stakeholder

The benefits and barriers of energy-saving programs adoption by stakeholder are presented in a tabular form in Table 3.

Table 3: Benefits and Barriers of energy-saving programs adoption by stakeholders

Stake-holder	**Benefits**	**Barriers**
End users	• Energy consumption reduction • Avoided production costs • Power losses savings • Reduce electricity bill	• Consumers are not very price sensitive • Difficulty in understanding electricity markets • Mistrust in electricity companies • Resistance to change • Unclear incentives for the market to reach energy targets • Lack of knowledge/interest in energy-related topics
System operators	• High volumes of data, enabling the prediction decisions in real-time • Improved data management and collection • Alleviation of high transaction costs • Reduction of grid impact of new charging infrastructure through demand management • Possibility to use EVs as dynamic distributed storage devices • New streams of revenue through the provision of ancillary services (for congestion and voltage management) • Avoidance of critical investments towards network enhancements due to the wide deployment of TwinERGY solutions	• Technical accounting rules not in line with the life spans of the products • Weak or lack of feedback structures • Research & development only at company levels constrain progress • Vague or non-existing incentives for distributed energy production

Authorities	• Provision of a clear roadmap for achieving compliance with European regulations for energy efficiency in buildings • Energy efficiency contribution to strategic priorities: - Reduce costs - Mitigate risk - Generate value	• Lack of project goals/objectives • Lack of knowledge of details in projects • Perceived increase of operation costs and risks with the introduction of new technology • Insufficient and inconsistent calculation methods • Lack of transparency in numbers • Innovation budgets coupled to project budgets • Weak or non-existing incentives for using the latest technology • Weak communication structures between companies, organizations, and academia • Lack of contact areas between energy user and energy producer
Retail and energy services	• Accurately forecast demand response potential • Improve customer loyalty and satisfaction • Avoid investing in peaking plants that operate for only a few hours per year • Long-term and credible commitment by the government to energy efficiency • Dedicated ESCO legislation and measures increased throughout Europe • Flexibility in the content and the preparatory procedure of a contract • Increase in EU grants, financial incentives, preferential loans	• Lack of knowledge about investment horizons, risks, and life spans • Low transparency of energy pricing models • Lack of national targets for community energy projects • Complicated tax rules, no tax exemptions • Lack of official and/or generally accepted ESCO definition • Lack of proper measurement and verification practices • Lack of well-established partnerships between ESCOs and sub-contractors

3/ Key Performance Indicator (KPI) Organization

In this section, the KPIs included in the TwinERGY proposal are carefully reviewed, discussed, and dissected into more specific KPIs. Therefore, first, the main KPIs discussed in the proposal are explained, then the KPIs relevant to the nine Use Cases and Pilot studies are presented, and lastly, all of these are summarized in section 5.2 (KPI Summary).

3.1 Main KPIs

Table 4 presents the KPIs included in the TwinERGY proposal as well as a brief description of each one.

Table 4: Main KPIs

Key Performance Indicators	Description
RES share in energy consumption	Measures the RES share: the total energy delivered to end-users as well as DSO's and TSO's losses for electricity and heat. It should be noted that exports/imports of electricity are not considered renewable energy (Eurostat, 2020).
Reduction of peak loads	Measures the reduction of the largest daily power consumption value.
Self-consumption ratio	Measures the amount of energy produced and consumed locally relative to the total production that is locally available from on-site generation units (most of the time the self-generated energy comes from PV). It is calculated as the ratio of self-consumption divided by the self-generated energy.
Penetration of dynamic energy tariffs	Measures the increase of residential consumers exposed to dynamic electricity tariff schemes (any such tariff, e.g., ToU, RTP, etc.) in TwinERGY pilot sites, hence quantifying the improvement in the penetration of DR mechanisms among these end-use consumers.
Active participation rate through user engagement and acceptance	Measures the sum of the number of users actively participating in the pilots in relation to the total that accepted participation.

Customer responsiveness	Measures how many customers have responded to a DR program following a DR signal sent to them, like a price change, as the total number of signals sent back by the customers as an absolute number or a percentage.
Total energy reduction against discomfort level constraint	Measures the reduction of energy consumption without exceeding a specific discomfort level/threshold. i.e., Given a Discomfort level X.
Customer satisfaction	Measures the user's satisfaction of overall participation in the pilot and the services that have been tested.
Demand flexibility	Measures the increase of the amount of load capacity participating in demand-side management at each pilot.

4/ Description of Use Cases

4.1 Use Case 1

Name of UC:
UC01 Home Energy Management

Responsible for UC:
STAM, German Pilot, Greek Pilot, Italian Pilot, UK Pilot

Scope and Objectives

<table>
<tr><th>Scope:</th></tr>
<tr><td>The scope of this UC is energy management in residential consumer premises to monitor the energy flows, maximize self-consumption and self-sufficiency.

The first step is to obtain a greater facilities' observability; the amount of static and dynamic monitored data will be gathered and then processed and analyzed.

Data gathering is crucial in the energy efficiency process and energy management; different actions will be taken depending on the data available, and eventually, the monitoring system will be improved.

The static parameters regard many aspects of the facility, such as:

• Typology (apartment/household/public building)
• Footprint area
• Number of floors
• Numbers of occupants
• Nominal Power supply
• Photovoltaic plant peak power
• Energy Tariffs timing and costs</td></tr>
</table>

The dynamic parameters refer to:

- *Energy consumption*
- *Photovoltaic production*
- *Indoor parameters (temperature and humidity)*
- *Weather conditions*

The data will be achieved and made available through an online graphical interface to improve the users' awareness about their energy profile in accordance with the UC8.

The main electrical appliances inventory and their weekly usage habits will deliver the optimal loads distribution during the week.

Through the GUI, the users can fulfil the typical usage habit of their main electrical appliances during the week. The usage routines could be updated and overwritten by the user whenever needed.

In relation to the energy monitoring and costs information, these data can be used to find and shape the optimal load profile, reduce costs in the energy bill, and maximize self-consumption.

Features under study

- *Smart and remote monitoring in the GUI*
- *PV generation*
- *Potential of self-consumption*
- *Load shifting optimization*
- *Peak shaving*
- *Electricity cost minimization*
- *Bills checking*
- *Power consumption anomaly detection*

Networks/Markets under Study

- *MV Network*
- *LV Network*
- *Energy markets*

Objective:
This Use Case is focused on the energy management of residential consumer premises and their ability to monitor and control loads, PV generation and energy storage in order to maximize self-consumption and self-sufficiency. • *Employment of load management provided by smart plugs' on/off control, considering dynamic tariffs to minimize energy cost to the end-user.* • *Employment of load management logics to improve self-consumption from PV; A Demand Response module, aiming to find the optimal electrical loads distribution within the day in the week taking into account energy cost, peak shaving, and users' comfort.* • *Flexibility modelling so the consumers can actively participate in demand response programs.* • *Checking of requested power versus nominal power of buildings' main loads.*

Narrative of the Use Case

Actors&Roles, Names and Types:
☒ DSO ☐ TSO ☒ End Customers (MV/LV) ☐ DER Customers ☐ Regulator ☐ Municipality/Local Authority ☒ Aggregator/Flexibility Operator ☒ Service Provider ☐ *Other:* **Specific Roles (if applicable)** *☐ System Optimiser*

☐ *Data Manager* ☐ *Smart Grid Operator* ☐ *Neutral Market Enabler* ☐ *Contraints Market Operator* ☐ *Customer Relationship Manager* ☐ *Other 3rd Parties Relationship Manager* ☐ *System Security Manager* ☐ *Other:*

Short Description:
In this Use Case the energy management of residential consumer premises is focused on through: 1. *Monitoring main electrical appliances and power lines* 2. *Shaping the energy users typical routines* 3. *Controlling loads with a smart plug* 4. *Generating PV energy* 5. *Storing the generated energy* 6. *Usage loads optimization minimizing costs and power peak demand*

4.2 Use Case 2

Name of UC:
UC02 RES Generation in domestic and tertiary buildings

Responsible for UC:
IES, Bristol Pilot, German Pilot, Italian Pilot

Twinergy has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 957736

Scope and Objectives

Scope:
This use case has the goal to create further renewable sources and infrastructure to increase the RES share in public and private buildings. The use case is being applied to three of the pilot sites for the TwinERGY project, with different aims for each specific to the location in question: 1. *Bristol: Community investment in local energy infrastructure, focusing on local RES (both present and future potential) both from an energy production point of view and also taking into account how they would operate in any future local energy market/community grid framework etc.* 2. *Hagedorn Village: Increased uptake of locally produced renewable energy, enabling increased flexibility of the local microgrid and increased social engagement in the use of RES.* 3. *Benetutti Smart Community: Increased integration of RES in the community grid, which will enable optimisation of building energy consumption through DR and participate in a new local energy trading platform.* *Each of the pilot site objectives are quite similar in the context of this use case, but the plan will be still to be as flexible as possible to allow for any specific requirements of one location so that the optimal solution can be found for local RES in the community.*

Objective:
This use case is aimed at maximising both the present and future RES generation and usage in public and private buildings across three of the four pilot sites. In line with this overall goal, the objectives of the use case are as follows: • *Minisimising energy costs for the end user through optimal use of the local renewable energy production* • *Minimising the overall carbon emissions produced by the community* • *Maximising the use of the local RES through supporting infrastructure, such as battery storage and demand response algorithms.*

Narrative of the Use Case

Actors & Roles, Names and Types:

• *Aggregator* • *Retailer* • *Building/asset owner* • *End users*

***Short Description**:*
UC02 can be divided into these Primary Use Cases (PUCs): • *PUC02.01 Dispatch of existing RES in domestic and tertiary buildings to minimise cost* • *PUC02.02 Dispatch of existing RES in domestic and tertiary buildings to minimise carbon emissions* • *PUC02.03 Optimal future energy storage to maximise RES production* • *PUC02.04 Maximum future RES capacity according to the physical constraints (e.g. roof space, cable sizes) of the pilot site* • *PUC02.05 Maximum future RES capacity determined by present/future V2G capacity as determined by the TwinEV module* • *PUC02.06 Optimal CHP solution specific to the pilot site in terms of capital costs and network capacity* • *PUC02.07 Optimal scenario of future energy storage and RES to minimise energy costs for the end user* • *PUC02.08 Optimal scenario of future energy storage and RES to minimise carbon emissions* • *PUC02.09 Optimal domestic and tertiary demand response, based on RES, to minimise cost* • *PUC02.10 Optimal domestic and tertiary demand response, based on RES, to minimise carbon emissions* *There are no Secondary Use Cases (SUCs) related to UC03.*

4.3 Use Case 3

Name of UC:
UC03 Grid capacity enhancement utilizing e-mobility

Responsible for UC:
ETRA I+D, Mytilineos (Greek Pilot Site), TH OWL (German Pilot Site)

Scope and Objectives

Scope:
Electrical Vehicles (EVs) have a dual nature. In the first place, they act as a transport mean when they are on the move. In the second place, they can also be a grid-connected battery when they are parked and plugged. Taking advantage of their second nature, EVs are able to transform the stress on the electric grid into the opportunity to act as a flexible asset. Smart Charging through an external control system, accompanied by Vehicle-to-Grid connexion would lead the EV owners to participate in specific markets that could generate relevant benefits for the energy sector, not only in terms of grid management but also in environmental terms since the transport sector in Europe is responsible for over 25% of greenhouse gas emissions. The adoption of EVs as a distributed storage asset lead to a more decarbonized infrastructure. Furthermore, managing the charging process through time schedule and power profiles will open new opportunities to not only EV owners but also to flexibility markets: smart EV charging can integrate a large share of Renewable Energy Sources (RES) throughout the modification of the power demand curve, reducing the system costs and supporting as well the decarbonization of neighborhoods as well. Consequently, EV will enable improved system management in terms of voltage control and grid congestions. *Through the application and study of this Use Case in two of the TwinERGY project pilot sites (Athens in Greece and Hagedorn Village in Germany), EVs will be analyzed as a distributed storage asset for grid purposes. In collaboration with Vehicle-to-Grid connection, EV smart charging would allow the grid to stabilize through the integration of RES and the possibility to participate in energy flexible markets. Additionally, Smart Charging would benefit EV users in terms of economic performance by reducing energy costs when charging, through the scheduling of their charging sessions. EVs as a distributed storage asset could also have an influence in the performance of Distributed System Operators (DSOs). Batteries could help these entities in the congestion and the voltage management, taking advantage of the flexibility that batteries can provide when they are connected through V2G connectors in charging points. In addition, the use of Smart Charging in EV would lead to more decarbonized neighborhoods, throughout the integration of RES from the energy mix or renewable surpluses detected in the charging processes.*

Features under study

- *Smart Charging*
- *Vehicle-to-Grid (V2G) Capability*
- *Participation in Demand Response campaigns*
- *Participation in Energy Markets*
- *Participation in Local flexibility markets*
- *Voltage Control and Grid Congestions through DSO*
- *Integration of RES and surpluses*
- *Reduction of CO2 emissions*

Networks/Markets under Study

- *MV Network*
- *LV Network*
- *Energy markets*
- *Local Flexibility Markets*

Objective:
This Use Case is focused on analyzing the potential implementation of electromobility to use EVs as distributed assets for the benefit of the grid performance. Electromobility would be analyzed through this UC to carry out this purpose by: • *Use of EV batteries as a distributed asset to offer ancillary services to the DSO (Congestion and Voltage Management) through the integration by V2G connexion.* • *Smart charging scheme development for EV owners from which EV charging could focus on the use of green energy (both from the Renewable sources in the energy mix and the energy surpluses from renewable generating assets) as well as on the charging sessions costs minimization.* • *The use of EV batteries for participation in flexible energy markets using demand response campaigns.* • *Using smart charging profiles to generate EVs charging efficiency via the integration of RES, helping the decarbonization of neighborhoods.*

Narrative of the Use Case

Actors & Roles, Names and Types:

- *Aggregator*
- *Retailer*
- *Distributed System Operator (DSO)*
- *End consumers (MV/LV)/Prosumers*
- *EV user*
- *EVSE Operator*
- *Public Authorities*
- *VPP operator*

Short Description:
UC03 "*Grid capacity enhancement utilizing e-mobility*" *can be further depicted into these different basic-level actions:* *Primary Use Cases (PUC):* • *Management of Charging Stations* • *Smart Charging calculation* • *Searching for the most suitable station* • *Interaction with the energy infrastructure* • *Ancillary and Congestion management (DSO operations)* *Secondary Use Cases (SUC):* • *Data collection from EVSE* • *Data collection from EVs* • *User's authentication* • *Get free charging stations* • *Calculation of the route* • *Evaluation of a station* • *EV flexibility estimation* • *EV Load forecasting* • *Charging session schedule* • *Charging reschedule to follow grid requests* • *Charging reschedule to maximize RES integration (green electricity)* • *Charging reschedule to minimize charging costs* • *Payment process for charging session*

4.4 Use Case 4

Name of UC:
UC04 Prosumers empowerment in local energy trading markets
Responsible for UC:
WEC, University of Patras, ETRA, University of Bristol (Pilot site), Benetutti (Pilot site)

Scope and Objectives

Scope:
The scope of this use case is to provide solutions to transactive energy uses cases and enables grid decentralization and democratization by connecting the micro-grid operators to the DER managers and their customers. It aims for an integrated energy business model through energy service expansion, customer engagement and financial inclusion. It allows them to balance the grid and provide solutions to a number of grid problems, such as grid power quality and reliability. The core of this use case is a transactional platform that offers its participants to sell their flexible energy loads and excess capacity on an open market to the (micro) grid operators or to each other. Microgrid operators provide balancing and grid services at a local and micro-grid level. A micro-grid could be a collection of a) IoT devices, b) buildings, c) neighborhoods/substations, and d) regions that operate at a regional level to balance multiple neighborhoods, districts and/or substations. It could potentially include the high voltage grid. Each component of the system (e.g., device, building, neighborhood, distribution grid and transmission grid) is a self-contained ecosystem, replicated and nested within the next layer of the system, like in a fractal configuration. All components operate with identical information and control models and each have operational decision-making capabilities. This platform offers a path to grid decentralization, energy democratization, and a way to effectively leverage and monetize the emerging DER infrastructure. *The Transactive Energy Module (TEM), based on Hybrid Blockchain technologies will be developed to solve current intractable optimization problems and create a premiere Transactive Energy (TE) protocol layer settlement process, marketplace, and governance framework to allow energy-related Apps to be written and interoperate with each other.*

Through the application and study of this Use Case in two of the TwinERGY project pilot sites (Bristol in the United Kingdom and Benetutti in Italy), grid infrastructures would be analyzed to implement state-of-the-art equipment that can monitor and track energy consumption and distribution.

Pilot sites, consisting of apartment buildings and individual houses will be equipped with smart meters, EV charging points, local and public storage facilities and IOT devices such as smart plugs. These are integrated with the Transactive Energy Module giving prosumers a powerful insight of their power consumption and redistribution to the local energy market (LEM).

The TEM will allow for prosumers to buy and sell energy from the LEM. It will also allow TE participants to transact in a P2P configuration outside an organized LEM/DSO or an ISO/TSO market. These transactions are stored as an immutable record on the blockchain specifying the actors participating in the transaction and the origin of the energy.

To further support the LEM, the TEM will process and broadcast price forecasting of the DNO and LEM. Other Twinergy modules will be able to listen to the broadcast and make energy consumption or discharge decisions on behalf of the prosumer.

For non-ISO/TSO and non LEM/DSO organized energy market transactions one pricing option could be to use a double-sided market in which TE participants pay a unique price based on their preferences and local supply and demand conditions (analogous to the stock market). Another option could be to use a proxy market price using a reference market price of the LEM organized market or the ISO/TSO market, (e.g., the 5-minute real-time auction price.

Features under study

- *Granular monitoring of energy consumption behind the meter*
- *Use of private and public storage facilities within a concealed grid infrastructure*
- *Technical limitations of tracing electrons (units of energy)*
- *LEM Price calculation and forecasting*
- *Social incentivisation for delivering energy to the LEM*

Networks/Markets under Study

- *Regulatory limitations of peer-to-peer transacting of energy*
- *Regulatory limitations of financial transactions for energy without involvement of a DNO or DSO*

Summary of Benetutti pilot site

- *The Benetutti pilot site consists of a neighborhood of 120 buildings of which 20 participate. Two of the participants are public places being a primary school and a nursery.*
- *Every participating house will have a PV installation. The KwH output of each installation is different.*
- *One participating house has a battery.*
- *Every participating house will be installed with a shelly cloud smart meter*
- *Every participating house will be provisioned with smart plugs*

Summary Bristol pilot site

- *The Bristol pilot site consists of 1 campus building and 10 residential homes. Participants are yet to be selected.*
- *Every home will be provisioned with a smart submeter.*
- *There will be a few houses with a PV installation.*
- *There will be 1 or 2 houses that will receive a Tesla battery.*
- *All participants will receive smart plugs.*
- *There will be no public storage facility.*

Objective:
This Use Case is focused on analyzing the potential implementation of Transactive Energy in *the benefit of the grid performance. Also, to empower prosumers by allowing them to trade the energy they produce. The use case is also focused on creating a Local Energy Market (LEM) and calculate dynamic energy pricing for the same. To carry out this purpose, Transactive Energy would be analyzed through this UC by:* *Implementation* • *Participating houses and appartment buildings on the pilot sites are / or will be equiped with smart meters. Behind the meter a combination of IOT devices are available such as smart sockets, HVAC systems and so forth. This also includes PV systems, home turbines, electric vehicles and other appliances that can generate or discharge energy. These are connected to the TwinERGY data modules* • *The data generated by the aforementioned devices can be used by other modules in order to make decisions on the behavior of applicances. This includes the decision to distribute energy back into the grid, move the energy to public storage facility or to provide the energy to another prosumer in the TwinERGY ecosystem.*

• *All energy transactions are recorded on a private permissioned blockchain (PPB).*

Narrative of the Use Case

Actors & Roles, Names and Types:
• *Aggregator* • *Distributed System Operator (DSO)* • *Consumers / Prosumers* • *Prosumer Consortium* • *Virtual Power Plant Operator (VPP)*

Short Description:
UC04 Prosumer's empowerment in local energy trading markets can be further depicted into these level actions. *Primary Use Cases (PUC):* • *Management of energy distribution behind the meter* • *Data collection from smart appliances, PV systems and batteries* • *Recording transactions of energy distributed back into the grid or to a private or public storage facility* • *Calculation and broadcasting of LEM pricing compared to DNO/DSO pricing* • *Optimal scheduling of LEM Assets (e.g., flexible loads, EVs etc.)* *Secondary Use Cases (SUC):* • *Recording transactions of energy between prosumers* • *Recording transactions of energy between prosumer consortia* • *Recording metering and sub-metering (e.g. HVAC, electric water heater etc) time series* • *Forecasting generation and load data* • *Processing the energy mix (solar, wind, bio, gas, nuclear, coal, etc.) to make informed decisions on peak energy consumption* ***Use Case Function description*** *"Create account"* • *Prosumer joins TwinERGY project*

- *Receive signal from other TwinERGY module to create prosumer account*
- *TEM confirms account created*

"Register Device"

- *New device joins TwinERGY ecosystem*
- *Receive Signal from other TwinERGY module to register a device (PV, HVAC etc.)*
- *Signal includes owner and TEM creates relation between prosumer and device*
- *TEM confirms device is registered and relation created*
- *(2) Function to remove devices*

"Register Consortium"

- *New prosumer consortium is formed*
- *Receive Signal from other TwinERGY module to register a consortium*
- *Signal includes participants and devices creates consortium relations*
- *(2) Function to add and remove prosumers and devices*

"Calculate and broadcast LEM and DSO/DNO Pricing"

- *TEM receives input data from other Twinergy modules*
- *TEM receives input data from DSO/DNO*
- *TEM calculates LEM pricing*
- *TEM broadcasts LEM/DSO/DNO pricing on set interval*
- *TEM records pricing on the blockchain*

"Process energy transaction"

- *TEM receives request from other Twinergy module or device to process a transaction*
- *Data input includes prosumer, device, units and destination*
- *TEM processes and settles the transaction*
- *TEM records transaction on the blockchain with reference to price hash*

"Communicate an account balance"

- *TEM receives request from another Twinergy module to communicate the balance an account*
- *Data input includes the ID of a Prosumer, Prosumer Consortium or Device*
- *TEM communicates balance*

"Communicate transaction history"

- *TEM receives request from another Twinergy module to communicate the transaction history of an account*
- *Data input includes the ID and date range of a Prosumer, Prosumer Consortium or Device*
- *TEM communicates an array of transaction*

"Load and generation forecast"

- *TEM receives input data from DSO/DNO*
- *TEM receives input data from TwinERGY digital twin*
- *TEM calculates day ahead load and generation forecast*
- *TEM broadcasts load and generation forecast*

4.5 Use Case 5

Name of UC:
UC05 Enhance grid flexibility through DER Management • *PUC05.01 – Grid status calculation and bottleneck detection* • *PUC05.02 – Prediction of energy consumption and RES production* • *PUC05.03 – Utilizing the Virtual-Power-Plant*

Responsible for UC:
Benetutti (Italian Pilot Site), TH OWL (German Pilot Site), STAM, IES

Scope and Objectives

Scope:

The generation of renewable energy sources (RES) can, in most cases, is not controlled and it is therefore crucial to find ways to harvest these types of energy when they are available. Thus, it is necessary to utilize methods that make the energy accessible for longer periods of time and be able to make accurate forecasts about the estimated energy generation so the energy consumption and distribution can be planned accordingly.

Currently, there is a big imbalance between the production and the consumption of RES, especially in regions that generate large amounts of RES power. Over the course of a day there may be periods where wind turbines or PV-systems generate more energy than is needed or can be consumed at the time. In order to keep the power grid stable, these energy sources have to be temporarily shut down, leading to an unused RES-potential of several TWh per year (e.g., 6,3 TWh in 2019 in Germany).

It is therefore essential to find intelligent ways of making the power demand more flexible and store the excess of produced energy, so that potential RES power is not wasted and the energy production sector in Europe can profit from further decarbonization. Another potential advantage of such intelligent energy storages is their very fast response time that can help stabilizing the power grid by reacting to temporary energy shortages in a timely manner.

Features under study:

- *Real-time grid status calculation*
- *Real-time grid bottleneck detection*
- *Real-time consumption level prediction.*
- *Real-time RES production level prediction.*
- *Real-time testing and evaluation of changes to grid switching behavior.*
- *Electric battery storage*
- *Home energy management system*

Networks/Markets under Study:

- *Low-Voltage (LV) Network*
- *Medium-Voltage (MV) Network*

PUC05.01 is related to grid stability and grid monitoring. While most of the current electricity grid was built upon default values solely defined by the energy demand, the penetration of the grid with renewable energy sources, electric charging infrastructure and electrical driven HVAC modifies the energy flow. Novel smart meter infrastructures, different sensors and *computational functions provide the ability to control and protect the grid infrastructure in real-time by analyzing loads at specific nodes and deploying countermeasures if necessary.*

Features under study:

- *Real-time grid status calculation*
- *Real-time grid bottleneck detection*

Networks/Markets under Study:

- *Low-Voltage (LV) Network*
- *Medium-Voltage (MV) Network*

PUC05.02 is related to predicting the consumption loads and RES production when applying DER management. To enable flexibility enhancements within the power grid, it is necessary to accurately predict future consumption load levels as well as production quantities of RES. This information allows DSOs to proactively apply changes to the switching behavior in the grid and distribute energy flows as well as energy reserves in battery stores more efficiently. Based on various information sources such as weather forecasts and user-behavior analysis, accurate predictions can be made, and their effects simulated. Unwanted feedback-loops caused by changes to the grid are identified beforehand and taken into consideration.

Features under study:

- *Real-time consumption level prediction.*
- *Real-time RES production level prediction.*
- *Real-time testing and evaluation of changes to grid switching behavior.*

Networks/Markets under Study:

- *Low-Voltage (LV) Network*
- *Medium-Voltage (MV) Network*

PUC05.03 describes the integration and utilization of a virtual power plant in the community. The objective is to maximize the production of renewable energy as well as acting as a grid stabilizing component. Therefore, reliable and precise control and coordination of the VPP components is necessary.

While sun or wind powered energy producers can be part of the VPP by shutting down production in times of low energy demand, the scope is narrowed down to batteries. Since the overall objective of the project is to maximize the usage of renewables, shutting off these *producers would be counterproductive to these goals and should only be considered as an ultima-ratio.*

Features under study:

- *Real-time grid status calculation*
- *Real-time grid bottleneck detection*
- *Electric battery storage*
- *Home energy management system*

Networks/Markets under Study:

- *Low-Voltage (LV) Network*
- *Medium-Voltage (MV) Network*

Objective:

In this Use Case congestion management is operated and tested. Specifically, different forecasts for loads and RES production are tested to measure combined network data and calculate the network status in real time. This includes testing the feedback- and switching-behavior as well as reactions of the HEMS towards changes of the network state.

- *Improving grid flexibility and stability by utilizing demand response mechanisms and energy storage capabilities.*
- *Increasing local RES share by increasing their usage in times of higher production, thus avoiding temporary shutdowns of RES facilities.*
- *Optimizing VPP through services offered to DSOs.*

PUC05.01 is focused on the grid status calculation and bottleneck detection. Based on this objective, grid loads at specific points can be determined which allows the deployment of various optimisation approaches to improve the grid stability and quality of service.

PUC05.02 objectives are:

- *Use information about weather forecasts to predict RES energy production.*
- *Use the information gained from consumer behavior analysis and historic data to predict consumption levels for individual households or quarters for specific time periods.*

• *Simulate changes to the grid switches using the forecast information and find an optimal configuration with highest efficiency and no feedback loops.* *PUC05.03 objectives are:* • *Use the battery to store excess renewable energy.* • *Use charged batteries in times of high demand and low RES production.*

Narrative of the Use Case

Actors & Roles, Names and Types:
• *Aggregator/Flexibility Operator* • *Distribution System Operator (DSO) – PUC05.01 to PUC05.03* • *End-users/consumers – for PUC05.02 and PUC05.03* • *Main battery storage operator in Hagedorn – for PUC05.03*

Short Description:
UC05 "Enhance grid flexibility through DER Management" can be further depicted into these Primary Use Cases (PUCs): • *PUC05.01. Grid status calculation and bottleneck detection* • *PUC05.02. Prediction of energy consumption and RES production* • *PUC05.03. Utilizing the Virtual-Power-Plant* *There are no Secondary Use Cases (SUCs) related to UC05.* *PUC05.01 starts when the last calculation ends or in an appropriate task runtime. It is a monitoring process.* *The process in this use case is the following:* 1. *The DSO collects all relevant data from smart meters and grid-integrated sensors at various specified nodes. This includes voltage-levels, currents, power, power factor and overload conditions.*

2. *The DSO estimates the grid state of all other nodes that were not directly measured by interpolating the existing measured data and using the available specification information of individual hardware components within the grid (network model).*
3. *The DSO examines the measurements and calculated data for all nodes and checks whether they are within their specified thresholds or if certain nodes are experiencing bottlenecking.*

If there are bottlenecks detected, the DSO starts the local countermeasure procedure. The countermeasure procedure depends on the availability of controllable loads, it could be interlinking two grids, the control of battery storage for auxiliary services or the control of public charging infrastructure.

PUC05.02 starts at 00:00 o' clock on any day. The process below is regularly repeated in specified time intervals throughout the day. This can be every 3 hours or more frequently.

1. *Information about the upcoming local weather conditions is retrieved, with a special focus on wind speeds and hours of sunshine.*
2. *All available RES in the local area for which the forecasted weather conditions apply are checked, and their level of energy production is predicted.*
    a. *This includes considering individual RES equipment and their estimated energy production based on their specifications. This requires all RES specs to be readily available.*
    b. *Additionally, the data can be supplemented with historical data of weather and production levels to accommodate for deviations from the specifications, such as in the case of wear.*
3. *Based on previous analysis of consumer behavior in the local area, supplemented by historical measurement data, the consumption levels of individual households or quarters are predicted based on the current time of day, weekday and weather conditions (with a focus on temperature and sunshine).*
4. *All gathered forecasts are used by the DSO to optimally reroute energy flows within the grid by adapting the grid switching behavior in a simulated environment to maximize RES consumption and grid stability.*
    a. *This includes decision making processes to decide where to charge or discharge battery storages.*

b. *Negative effects such as feedback loops shall be detected this way before they actually appear.*

5. *The previously tested changes to the power grid are deployed in real life and effects are monitored in real-time.*

    a. *Any unwanted effects such as unexpected feedback loops that were not identified beforehand shall be mitigated by corresponding additional changes to the grid switches.*

The process is repeated at a later point in time.

PUC05.03 begins on a sunny day.

1. *While it is still early just before dawn, the PV-systems in Hagedorn have not yet begun any production. Still, some people have already woken up and are preparing themselves for work. At this time, the first rooms are lit and appliances such as coffee machines are started for breakfast. Because it is still dark, the PV systems on the roofs cannot contribute to the energy production, yet. However, during the past day and with the help of wind turbines, they were able to charge the energy storages in the village, which can now be used to power the households.*

2. *As the sun rises, the production of solar energy is also increasing until there is a balance between the demand and the production of energy. Any excess energy produced from this point on, is used to charge the battery storages at the pilot site, since they were used up to some extent in the morning and during the night.*

3. *When the sun begins to set, the storages are sufficiently charged to support the households with enough power throughout the upcoming evening and night. This is supplemented with additional power reserves coming from wind power, which is not dependent on sunlight.*

4. *The whole process is repeated on the next day.*

4.6 Use Case 6

Name of UC:

UC06 Consumers engagement in Demand Side Management Programs utilizing feedback mechanisms

Responsible for UC:
ED, Greece Pilot, Italy Pilot

Scope and Objectives

Scope:
The scope of this UC is limited to feedback-based demand-side intervention strategies applied at the residential level. This UC will explore manners that DSO and/or Retailers may apply as a matter of increasing residential awareness resulting in the essential engagement of residential end-user into demand-side management programs. Demand response relies on the basic principle of exploiting certain flexibility that power consumption has (i.e., type of numerous end-user which are managed by a retailer/aggregator), and its implementation implies technical infrastructures and a scheme that is adopted by the market. In regard to technical infrastructures, this UC will particularly explore automated interfaces that can steer the customer to participate in demand-side management schemes in a streamlined manner. From the market design, this UC will exploit demand-side management that either relies on the participation of end-user due to responding to market price signals or incentives (i.e., price-based or incentive-based schemes) thus changing normal electricity consumption patterns. ***Features under study*** • *DSO and/or Retailer's feedback mechanism* • *Residential awareness* • *Residential engagement* • *Residential demand flexibility* • *Residential energy use* ***Networks/Markets under Study*** • *LV Network* • *MV Network*

Objective:
The objective of this UC is to encourage the residential consumers' participation in the developed demand response programs, utilizing user-friendly interfaces for acquiring feedback regarding energy-related actions. This UC targets engaging local consumers in implicit demand response programs that are realized through the combination of dynamic pricing schemes, feedback mechanisms, and human-centric features that allow consumers to alter their energy consumption patterns and provide flexibility to the electricity retailer without compromising their comfort and wellbeing. Such feedback mechanisms are meant to be achieved under this UC with the consideration of: • *metering and sub-metering data from the local client of Retailers, IoT and sensing data from consumer premises* • *demographic information* • *EV charging information* • *Weather via aggregation and disaggregation.* *Responsible retailers may leverage the above data along with incurred advanced analytic at their premises as a matter of determining the consumer's spatio-temporal flexibility profiles and their potential capacities to participate in demand-side integration programs. The management of the connected clients by the retailers may explore the adoption of techniques on clustering the flexibility profiles given the spatial (i.e., neighboring) and temporal traits. The goal will be to establish optimal Virtual Power Plant (VPP) composition to deliver added value services to the electricity retailer.*

Narrative of the Use Case

Actors & Roles, Names and Types:
• *Aggregator/Flexibility Operator* • *Distributed System Operator (DSO)* • *End consumers (MV/LV)/Prosumers*

Short Description:
Deploy and scale up a user-friendly building energy management system that supports consumers managing self-consumption, and maximizes self-sustainability, increases residential awareness and engagement to demand-side management programs, and reduces reluctance and fear of participation in demand response programs. *Primary Use Cases (PUC)* • *Spatio-temporal clustering of flexibility profiles* • *Management of VPP (clustered end-users)* *Secondary Use Cases (SUC)* • *Data-collection from smart-meters* • *Data-collection from sub-metered IoT devices* • *Aggregation weather data*

4.7 Use Case 7

Name of UC:
UC07 Consumer's engagement in demand response programs utilizing a socio-economic context
Responsible for UC:
ED, Italy pilot, Germany pilot, the British pilot

Scope and Objectives

Scope:
This UC entails enabling a set of social context drivers for energy-related behavior changes by exploiting social interaction and cultural values. The aim is to influence efficient energy exchanges between households relying on consumer attitudes towards benefit and comfort.

The latter is foreseen to take place based on qualitative and quantitative techniques, which have embedded prosumers' contexts.

Features under study

- *Socio-economic variables*
- *Cultural dimensions (individual- and community-level)*
- *Behavioral data (e.g., adoption intention, engagement, energy exchanges between households, consumer attitudes (benefit in conjunction with comfort)*

Networks/Markets under Study

- *LV Network*
- *MV Network*

Objective:

Enable Social context drivers for energy-related behavior changes, by utilization of social interactions and cultural values to influence energy exchanges between households, and consumer attitudes towards benefit and comfort. Within this UC the following aspects will be taken under consideration:

- *Socio-economic variables*
- *Cultural aspects, at the individual- and community-level (e.g., Hofstede cultural dimension or Schwartz Human Values Theory)*
- *All of these will be independent variables of attitude and actual users' behavior (e.g., measuring adoption intention, speed-up engagement, energy exchanges between households, among others)*

The main objective of this UC will be to leverage the inputs above by conducting behavioral analysis, as a matter of employing community-based social marketing to engage participants through continuing conversation, active debates and organize Living Labs. From the individuals' perspective, certain recommendations will be provided by the social network as a matter of improving their consumption profiles and habits. The latter aims to consider a disaggregation algorithm that will allow determining appliance-specific consumption, using merely the aggregate power signal of a household as input. Each appliance relates to a unique energy consumption pattern, characterizing and differentiating appliance's operations from the aggregate signal. At the community level, competition among neighboring end-users will take place via the utilization of social network modules that will be performed based on

gamification functionalities. The competition, in turn will be relying on specific KPIs such as energy efficiency, participation in the local community, utilization of shared assets etc, as a matter of providing the corresponding rewards.

Narrative of the Use Case

Actors & Roles, Names and Types:
• *End consumers (MV/LV)/Prosumers*

***Short Description**:*
This task will also focus on the barriers consumers face when adopting Demand Response, be it cultural barriers, knowledge, or social limitations like energy vulnerable customers. To gather this customer perspective, smartEn will work together with consumer organizations. The outcome will be a reasoned analysis of all kinds of barriers customers and service providers face and how they can limit the implementation of TwinERGY business models. *Primary Use Cases (PUC)* • *Behavioral analysis of end-users* • *Social marketing to engage customers via competition* • *End-users' engagement on utilization of shared DERs* • *Enable co-creation for end consumers, service providers and public authorities* *Secondary Use Cases (SUC)* • *Collection and analysis of socio-economic variables* • *Collection and analysis of cultural dimensions (individual- and community-level)* • *Collection and analysis of behavioral data* • *Collection of forecasts from Digital Twin Platform* • *User's profile creation* • *Collection of consumption profile* • *Data collection regarding shared DER infrastructures* • *Evaluation of end-user's profile based on certain KPIs* • *Calculation of rewards* • *Social networking functionalities*

4.8 Use Case 8

Name of UC:
UC08 Consumer's engagement in demand response programs utilizing personalized comfort/health-oriented services

Responsible for UC:
STAM, Greece pilot, Italy pilot, Germany pilot

Scope and Objectives

Scope:

The scope of this UC is to demonstrate innovative approaches to obtain consumers' realistic comfort/wellbeing level with minimum intervention.

Innovation often faces matters related to distrust and misunderstanding.

To improve the people participation in DR programs, one of the main tasks to tackle is increasing their awareness of the topic to reduce their fear of comfort losses.

The main idea is to make the users aware of their current energy usage routines.

- *Are they healthy?*
- *Are they fine compared to the average of similar facilities?*
- *Does some unidentified energy consumption pattern exist?*

Through a user-friendly Graphic Unit Interface, the energy monitoring information can be shown together with target and good practice threshold of facilities with similar characteristics.

Moreover, it is going to suggest to the users, the optimal electrical appliances distribution during the week and the benefits, in terms of costs and energy consumption reduction.

Starting from that, it is already possible to drive the users into autonomous behavioral change and toward more efficient and healthier energy routines.

The next step is the real user's comfort analysis.

Comfort is a parameter specific for each person; even married couples can have completely different energy consumption or indoor environment preferences.

Because of that, a close-loop with the users is an interesting analysis target.

Depending on the availability of the users, this use case aims to gather comfort feedback through the GUI and the physiological data through wearable devices.

In relation to the indoor and energy monitoring system data, the comfort analysis will enter into the optimal energy solution for DR.

Features under study

- *Sensing data from consumer premises,*
- *Energy price information,*
- *Demographic information,*
- *EV charging information,*
- *Weather data*
- *Comfort data*

Networks/Markets under Study

- *LV Network*
- *MV Network*

Objective:

Show that the utilization of low-cost wearable devices through which specific physiological data can be unobtrusively obtained and advance unsupervised classification techniques comprise an appropriate combination to accurately depict consumers' comfort/well-being level.

- *Increase the users' awareness about their energy patterns*
- *Shown the average targets expected and a threshold logic*
- *Gather the physiological comfort parameters and their feedback*
- *Shape the best practice based on the users' specs*

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Narrative of the Use Case

Actors & Roles, Names and Types:
☐ DSO ☐ *TSO* ☒ *End Customers (MV/LV)* ☐ *DER Customers* ☐ *Regulator* ☐ *Municipality/Local Authority* ☐ *Aggregator/Flexibility Operator* ☐ *Service Provider* ☐ Other: Charging Point Operators **Specific Roles (if applicable)** ☐ *System Optimiser* ☐ *Data Manager* ☐ *Smart Grid Operator* ☐ *Neutral Market Enabler* ☐ *Contraints Market Operator* ☐ *Customer Relationship Manager* ☐ *Other 3rd Parties Relationship Manager* ☐ *System Security Manager* ☐ *Other:*

Short Description:
The TwinERGY services will analyze and promote non-intrusiveness, comfort and well-being preservation, respect of prosumer daily schedules as well as maximization of benefits through transparent and open participation in markets. It will also guarantee easy switching between DR service providers, vendor lock-in avoidance, customized DR service contracts and objective settlement and remuneration, thus establishing an energy democracy context and empowerment of prosumers to become active energy market players.

4.9 Use Case 9

Name of UC:
UC09 Consumer Engagement in Demand Response Programs Utilizing Digital Twin Prediction Capabilities for Dynamic VPPs

Responsible for UC:
IES, Bristol Pilot, German Pilot, Italian Pilot, Greek pilot

Scope and Objectives

Scope:
The main focus of consumer engagement in the demand response programs that utilise the digital twins of the TwinERGY pilot sites will be a human-machine interface in the form of an online interactive dashboards. Bespoke dashboards will be created for each of the pilot sites, the design of which will be informed by their specific requirements. Dashboards will be created for both the consumer and community digital twins, with specific users able to interact with and evaluate relevant information about their home/building/community. *In terms of the quality of data that is displayed and the accuracy of the demand response programs, it is very important that the required information and data is provided by each of the pilot site. The quality of performance of this use case is directly proportional to the input data, and so the data collection exercise is a vital pre-requisite to this use case.*

Objective:
The community Digital Twin will be the amalgamation of the individual consumers' Digital Twins and, as such, will be able to represent the main assets of the VVP.

Narrative of the Use Case

Actors & Roles, Names and Types:

- *Building owners*
- *Aggregators*
- *Pilot leaders*
- *DER Management Module project partner*

Short Description:

UC09 can be further divided into these Primary Use Cases (PUCs):

- *PUC09.01 Explicit Demand Response Automation and display at a consumer and community level.*
- *PUC09.02 Implicit Demand Response Calculation and Communication to the end-user at both a community and consumer level.*
- *PUC09.03 Implicit & Explicit DR actions summarised and displayed at a community level to the relevant user*
- *PUC09.04 Calculation of community-level flexibility which is made available to the DER management module for local network power flow optimisation, as well as any other project modules that require the information*
- *PUC09.05 Collation of consumer DT forecasts as inputs to the community DT for seemless integration of the two levels.*

There are no Secondary Use Cases (SUCs) related to UC09.

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5/ KPIs of Use Cases

In this section the nine TwinERGY Use Cases are reviewed (Table 5), and the KPIs which are most relevant to them are introduced. These findings are the basis for the resulting KPI table contained in section 5.3.

Table 5: Use Cases

Use Cases	Description	City of Athens - Greece	Benetutti Smart Community - Italy	Hagedorn Village - Germany	Bristol City -UK	Support Partner Involved
UC01	Home Energy Management	X	X	X	X	STAM
UC02	RES Generation in domestic and tertiary buildings		X	X	X	STAM
UC03	Grid capacity enhancement utilizing e-mobility	X		X		ETRA
UC04	Prosumers empowerment in local energy trading markets		X		X	KWMC and UNIVBRIS
UC05	Enhance grid's flexibility through DER management		X	X		TH OWL
UC06	Consumers engagement in Demand Side Management Programs utilizing feedback mechanisms	X	X			Suite 5 and Mytilinaios
UC07	Consumer's engagement in demand response utilizing a socio-economic context		X	X	X	IFC
UC08	Consumer's engagement in	X	X	X		UoP

	demand response programs utilizing personalized comfort/health-oriented services					
UC09	Consumer's engagement in demand response programs utilizing digital twins prediction capabilities for dynamic VVPs	X	X	X	X	Suite5 and ETRA

UC01 – Home Energy Management

This UC focuses on the energy management of residential consumer premises and their ability to monitor and control loads and generate and store PV in order to maximize self-consumption and self-sufficiency.

Relevant KPIs:

- Minimize energy cost for the end-user
- Improve self-consumption from PV
- Consumer participation in demand response programs

UC02 – RES Generation in domestic and tertiary buildings

This UC aims to create additional renewable sources (e.g., PV systems and CHP) and infrastructure (e.g., electric-l storage capacities and thermal storages), as well as to integrate existing renewable energy systems to increase the RES share in public and private buildings.

Relevant KPIs:

- Increase RES share in energy consumption of domestic and tertiary buildings

UC03 – Grid capacity enhancement utilizing e-mobility

This UC tests how EVs can be used as a distributed storage asset, able to stabilize the grid and lead to more decarbonized neighborhoods. Thereby advanced EV charging management features are required to unleash the full potential of e-mobility vehicles.

Relevant KPIs:

- Reduce congestion through ancillary services offered to DSOs
- Reduce energy costs for end-users of e-mobility (due to smart-charging)
- Reduce CO2 emissions (through smart charging of electronic vehicles)

UC04 – Prosumers empowerment in local energy trading markets

Build a decentralized transactional platform offering participants to sell their excess loads or capacity on an open market. Connecting micro-grid operators to DER managers and their customers to provide a solution for transactive energy and enable grid decentralization and democratization.

Relevant KPIs:

- Launch decentralized energy transaction platform
- Establishment of micro-grids
- Balance the grid
- Improve grid quality and reliability

UC05 – Enhance grid flexibility through DER Management

In this UC, congestion management is operated and tested. Specifically, different forecasts for loads and RES production are tested to measure combined network data and calculate the network status in real-time. This includes testing the feedback- and switching- behavior as well as reactions of the HEMS towards a change of network state.

Relevant KPIs:

- Improve grid flexibility and stability
- Increase RES share
- Optimize VPP through services offered to DSOs

UC06 – Consumers engagement in Demand Side Management Programs utilizing feedback mechanisms

This UC applies feedback-based-demand-side-intervention strategies from DSO and/or Retailers at the residential level to increase residential awareness and engagement to demand-side management programs.

Relevant KPIs:

- Increase residential demand flexibility
- Decrease residential energy use
- Increase awareness and engagement of residential customers in demand-side management programs

UC07 – Consumer's engagement in demand response programs utilizing a socio-economic context

This UC deploys qualitative and quantitative behavioral analysis to determine the of social interactions and cultural values to the energy exchanges between households, and consumer attitudes towards benefit and comfort.

Relevant KPIs:

- Employment of community-based social marketing
- Increase engagement in demand response programs

UC08 – Consumer's engagement in demand response programs utilizing personalized comfort/health-oriented services

This UC demonstrates innovative approaches to obtain consumers' realistic comfort/wellbeing level with minimum intervention. Utilization of wearable devices which obtain specific physiological data to accurately measures consumers' level of comfort and wellbeing.

Relevant KPIs:

- Obtain consumers' realistic comfort/wellbeing level
- Provide consumers with pertinent personalized feedback notifications

UC09 – Consumer's engagement in demand response programs utilizing digital twins' prediction capabilities for dynamic VVPs

This UC deploys Digital Twins with a human-machine interface to offer an interactive experience to consumers and communities. This will allow for automated explicit demand response processes integrated with platforms of relevant stakeholders (e.g., DSOs and aggregators).

Relevant KPIs:

- Automation of explicit demand response processes
- Optimize demand flexibility considering weather and energy system constraints

Engage members of Digital Twin communities to use interactive dashboard (to explore the model and information it contains)

5.1 KPIs of Pilot Studies

In this section, the four Pilot demonstrations of the TwinERGY project are reviewed. These findings are the basis for the complete KPI table in section 5.3. It should be noted that these are just summaries of the pilot demonstration and the related KPIs, therefore, not all details and specific KPIs are discussed.

Pilot Demonstration in Bristol, UK

Bristol's One City Plan aspires to connect all its citizens with services and transport that are efficient, sustainable, and inclusive. Thereby TwinERGY will enable them to make energy more affordable through intelligent grid DNR control processes and management. The Digital Twin technologies will be explored to increase citizen engagement, improve energy efficiency and promote sustainable behavior change.

Relevant KPIs:

- Minimize energy cost for the end-user
- Increased citizen engagement
- Improved energy efficiency
- Increase investments of prosumers in the energy system, data generation, and contribution to community schemes

Pilot Demonstration in Hagedorn in Hagedorn Village, Steinheim, North Rhine-Westphalia, Germany

Through the participation in the TwinERGY project and pilot study, the city administration of Hagedorn village wants to increase renewable energy use among the citizenry and inspire them to increase their interest in energy-related issues. Specifically, the low-voltage infrastructure will be improved and expanded through advanced measurement technology, electrical circuit technology, communication technology, and electrical storage. The goal is to make the whole neighborhood Smart Grid compatible.

Relevant KPIs:

- Achieve efficient energy use
- Higher RES share in energy consumption
- Significant increase in consumer interest (in energy-related measures)
- Increase the flexibility of micro-grid
- A larger share of self-produced solar power locally
- Increase customer satisfaction and social benefits
- Increase end-user participation by 50%

Pilot Demonstration in Benetutti Smart Community, Italy

The regions' currently poor connection with the national power grid and the non-existent connection to the natural gas network forces Sardinia towards electrification of their own energy system. Through the pilot study demonstration, the municipality aims to solve power fluctuation problems by developing a flexible and sustainable energy grid. Moreover, its citizens will be engaged in DR programs through economic incentives and user-friendly interfaces. The forecasting capabilities will create a knowledge base and system that can monitor and manage the energy exchange based on smart contracts and blockchain technology on a community level.

Relevant KPIs:

- Increase RES share
- Increasing consumer participation
- Balance the grid (reduce consumption during peak hours, increase it during low energy cost periods)
- Optimize energy consumption (through participation in demand response programs)
- Increase engagement of residential customers in demand-side management programs
- Provide consumers with personalized feedback notifications
- Maximization of the effectiveness of RES
- Minimize energy costs for the end-user
- Improve demand flexibility and stability

Pilot Demonstration in Athens, Greece

This pilot will focus on engaging local consumers in implicit demand response programs through a combination of dynamic pricing schemes, feedback mechanisms, and patronizable human-centric features. Specifically, metering and sensing data from local consumers will be analyzed to follow behavior profiling and forecasting for individual consumers. These will then be classified and segmented based on their actual, locally estimated flexibility. This analysis will act as a baseline for the realization of consumer-centric demand response programs.

Relevant KPIs:

- Increase engagement of residential customers in demand-side management programs
- Provide consumers with personalized feedback notifications
- Deliver clusters of flexibility profiles of consumers (against varying electricity prices)
- Minimize energy costs for the end-user
- Preserve comfort of consumers
- Balance the grid / Reduction of peak loads
- Automation of explicit demand response processes
- Comply with Energy Efficiency obligations by EC

5.2 KPI Summary

Table 6 illustrates the previously presented KPIs of Use Cases and Pilot studies in a summarized and structured format.

Table 6: KPIs of Use Cases and Pilot studies

KPIs	Literature	Use Cases	Pilot Demonstration
1. RES share in energy consumption		**UC02, UC05**	**Athens, Hagedorn, Benetutti**
1.1 Increase RES share	Olkkonen et al. (2018). DOI: 10.1016/j.energy.2018.08.210	UC05	Hagedorn, Benetutti
1.2 Increase RES share in energy consumption of domestic and tertiary buildings	Frangou et al. (2018). DOI: 10.1016/j.renene.2018.03.001	UC02	Athens, Benetutti
2. Reduction of peak loads		**UC03, UC04, UC05**	**Athens, Benetutti, Hagedorn**
2.1 Reduced congestion	Ghazvini et al. (2019). DOI: 10.1016/j.segan.2018.100185	UC03	Athens
2.2 Balance the grid	-	UC04	Athens, Benetutti
2.3 Improve grid quality and reliability	Ourahou, Ayrir, El Hassouni, & Haddi (2020). DOI: 10.1016/j.matcom.2018.11.009	UC04	Benetutti, Hagedorn
2.4 Optimize VPP through services offered to DSOs	Park & Son (2020). DOI: 10.1016/j.apenergy.2020.115222	UC05	Athens
3. Self-consumption ratio		**UC01, UC04**	**Hagedorn**
3.1 Improve self-consumption from PV	Gomez-Gonzalez, Hernandez, Vera & Jurado (2020). DOI: 10.1016/j.energy.2019.116554	UC01	Hagedorn
3.2 Establishment of microgrids	An, Lee, Yeom, & Hong (2020). DOI: 10.1016/j.apenergy.2019.114335	UC04	Hagedorn
4. Penetration of dynamic energy tariffs		**UC04**	**Bristol, Hagedorn**

4.1 Prosumer engagement in local energy trading markets	Cramer et al. (2019). DOI: 10.34890/555	UC04	Hagedorn
4.2 Increase investments of prosumers in energy system, data generation and contribution to community schemes	Inês et al. (2020). DOI: 10.1016/j.enpol.2019.111212		Bristol
5. Active participation rate through user engagement and acceptance		**UC06, UC07, UC08, UC09**	**Athens, Benetutti Bristol, Hagedorn**
5.1 Increase awareness of residential customers in demand-side management programs	Boogen, Datta, & Filippini (2017). DOI: 10.1016/j.eneco.2017.04.006	UC06	Hagedorn
5.2 Increase engagement of residential customers in demand side management programs	Parrish, Heptonstall, Gross, & Sovacool (2020). DOI: 10.1016/j.enpol.2019.111221	UC06, UC07, UC08	Athens, Benetutti, Bristol.
5.3 Employment of community-based social marketing	Gordon, Waitt, Cooper, & Butler (2018). DOI: 10.1016/j.jenvman.2018.02.046	UC07	Benetutti
5.4 Engage members of Digital Twin communities to use interactive dashboards	-	UC09	Bristol
6. Customer Responsiveness		**UC01, UC08, UC09**	**Athens, Benetutti, Hagedorn**
6.1 Increase consumer participation in demand response programs	Alasseri, Rao, & Sreekanth (2020). DOI: 10.1016/j.rser.2019.109490	UC01	Hagedorn, Benetutti
6.2 Provide consumers with personalized feedback notifications	Khosrowpour, Xie, Taylor, & Hong (2016). DOI: 10.1016/j.apenergy.2016.10.036	UC08	Benetutti, Athens

6.3 Automation of explicit demand response processes	Samad, Koch, & Stluka (2016). DOI: 10.1109/JPROC.2016.2520639	UC09	Athens
7. Total energy reduction against discomfort level constraint		**UC03, UC06**	**Athens**
7.1 Reduce CO2 emissions	-	UC03	Athens
7.2 Decrease residential energy use	Chatzigeorgiou & Andreou (2021). DOI: 10.1016/j.rser.2020.110187	UC06	Athens
7.3 Preserve comfort of consumers	Vázquez-Canteli & Nagy (2019). DOI: 10.1016/j.apenergy.2018.11.002		Athens
7.4 Comply to Energy Efficiency obligations by EC	Fawcett, Rosenow, & Bertoldi (2019). DOI: 10.1007/s12053-018-9657-1		Athens
8. Customer satisfaction		**UC01, UC03, UC08**	**Athens, Benetutti, Bristol, Hagedorn**
8.1 Minimize energy costs for the end user	Orlov, Sidorova, & Samoilov (2020). DOI: 10.1109/ICIEAM48468.2020.9111964.	UC01, UC03	Bristol, Benetutti
8.2 Obtain consumers' realistic comfort/well-being level	Ornetzeder, Wicher, & Suschek-Berger (2016). DOI: 10.1016/j.enbuild.2016.02.036	UC08	Athens
8.3 Increase satisfaction and social benefits	Shin & Managi (2017). DOI: 10.1016/j.enpol.2017.07.048		Hagedorn
9. Demand Flexibility		**UC04, UC05, UC06, UC09**	**Athens, Benetutti, Hagedorn**

9.1 Launch decentralized energy transaction platform	Han, Zhang, Ping, & Yan (2020). DOI: 10.1016/j.energy.2020.117417	UC04	Benetutti
9.2 Improve demand flexibility and stability	Chae & Rae (2016). DOI: 10.1016/j.apenergy.2016.07.021	UC05	Hagedorn, Benetutti
9.3 Increase residential demand flexibility	Stavrakas & Flamos (2020). DOI: 10.1016/j.enconman.2019.112339	UC06	Athens
9.4 Optimize demand flexibility considering weather and energy system constraints	Yongbao et al. (2018). DOI: 10.1016/j.enbuild.2018.08.003	UC09	Athens
9.5 Deliver clusters of flexibility profiles of consumers	-		Athens

5.3 KPI – Stakeholder Matrix

The KPI-Stakeholder Matrix presented in the following two pages visualizes the KPIs identified in the KPI Summary Table 7 and the involvement of the Stakeholder groups, thereby acting as a roadmap to assist stakeholders to be involved, satisfied, and informed in the pursuit of the applicable KPIs.

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Table 7: KPI Summary

	Key Performance Indicators (KPIs)													
	1. RES share in energy consumption		2. Reduction of peak loads				3. Self-consumption ratio		4. Penetration of dynamic energy tariffs		5. Active participation through user engagement and acceptance			
Stakeholder	1.1	1.2	2.1	2.2	2.3	2.4	3.1	3.2	4.1	4.2	5.1	5.2	5.3	5.4
Residential users	B	C	B	B	B	A	D	B	D	D	D	D	C	D
Commercial users	B	C	B	B	B	A	D	B	B	B	-	-	C	-
Industrial users	C	B	B	B	B	A	D	B	B	B	-	-	C	-
DERs	D	D	B	B	B	B	D	B	B	B	-	B	C	-
DSOs	C	C	D	D	B	D	B	B	B	B	-	B	A	-
TSOs	C	C	D	D	B	C	B	B	B	B	-	B	A	-
Policy-makers	A	A			D		A	D	A	A	D	D	A	D
Regulators	A	A			D		A	D	A	A	D	D	A	D
Aggregators			D	D	C	C	C	D	D	D	B	C	D	-
ESCOs			C	C	C	C	B	C	B	B	B	C	A	-

Stakeholder Mapping

A Minimum Effort	**B** Keep Informed
C Keep Satisfied	**D** Key Players

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	Key Performance Indicators (KPIs)										
	6.Customer responsiveness			7. Total energy reduction against discomfort level constraint		8. Customer satisfaction		9. Demand flexibility			
Stakeholder	6.1	6.2	6.3	7.1	7.2	8.1	8.2	9.1	9.2	9.3	9.4
Residential users	D	C	B	D	D	C	C	C	C	C	B
Commercial users	D	C	B	D	-	C	C	C	C	-	B
Industrial users	D	C	B	D	-	C	C	C	C	-	B
DERs	A	A	B	A	A	-	-	-	-	-	-
DSOs	A	A	B	A	A	B	A	D	D	D	D
TSOs	A	A	B	A	A	B	A	D	D	D	D
Policy-makers	A	A	D	A	A	D	A	A	A	A	A
Regulators	A	A	D	A	B	A	A	A	A	A	A
Aggregators	C	D	D	A	D	D	D	C	D	D	D
ESCOs	C	C	D	A	D	D	B	B	B	B	B

Stakeholder Mapping

A Minimum Effort	**B** Keep Informed
C Keep Satisfied	**D** Key Players

6/ Stakeholder Mapping

As one of the largest abstracts and citation databases of literature, Scopus was used for data retrieval for this analysis. The exported information encompasses citation information (Author(s), Author(s) ID, Document title, Year, Source title, volume, issue, pages, Citation count, Source & document type, Publication Stage, DOI, Open Access), and abstract and keywords (Abstract, Author keywords, Index keywords). The period used is from 2005 to 2021.

The following figures were retrieved using **bibliometrix** and **biblioshiny** R packages on RStudio, used to conduct bibliometric analysis and visualization. More than 200 articles were retrieved from Scopus using the following keywords: demand response, prosumers, TSO, DSO, aggregators, regulators, saving, stakeholder. In order to narrow down the voluminous results, the subject area was set to "**energy**".

The keywords plus "offers more descriptive trends than the author's assigned keywords" (Nasir et al., 2020). For this reason, the following co-occurrence network figure was retrieved using keywords plus. Figure 6 represents a co-occurrence network with keywords plus. It is a visualization of how frequently those keywords appeared together. The clustering algorithm used is "**Louvain**" and the normalization used is "**association**". Figure 7 represents the main information about the collection; the descriptive characteristics of the dataset.

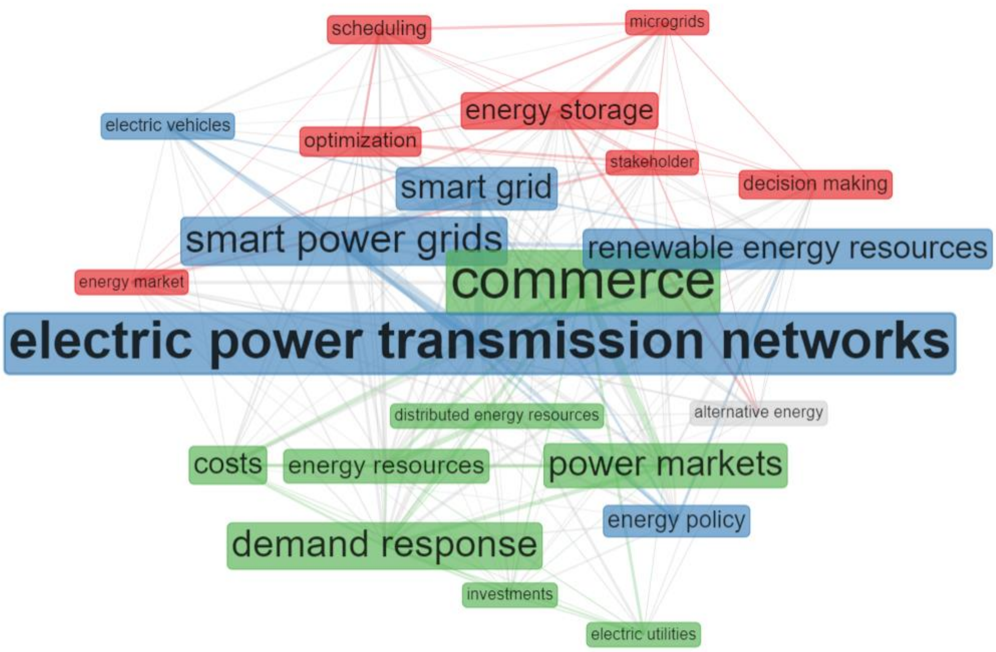

Figure 6: Co-occurrence network with keywords plus

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2005:2021
Sources (Journals, Books, etc)	79
Documents	213
Average years from publication	2.63
Average citations per documents	13.32
Average citations per year per doc	2.678
References	1
DOCUMENT TYPES	
article	141

Figure 7: Main information about the dataset

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7/ Interviews

7.1 Interviews with stakeholders

Semi-structured in-depth interviews were developed with energy field stakeholders and consumers to gain insights on Stakeholders' requirements and Use Case scenarios. The interviews had the following objectives: (1) to understand participants' attitudes regarding green energy engagement and (2) to clarify the barriers and drivers for energy-saving and green energy production.

Research Procedures

In total, 57 semi-structured interviews and workshops lasting 30-60 minutes were developed with energy field stakeholders (n = 7) and consumers (n = 50). Following participants' informed consent, interviews were recorded and transcribed, respecting TwinERGY's Ethical Guidelines and GDPR procedures. Table 8 provides further detail regarding the stakeholders.

The data analysis technique chosen is the technique of content analysis. Franco (2008) argues that content analysis is a research procedure where the starting point is the message, which expresses a meaning from oral or written, gestural, figurative, or documentary methods. For Bardin (2004), this method of analysis has the objectives of overcoming the uncertainty of the information and generating the enrichment reading, as content that confirms the subscribed message is discovered, generating a greater understanding of the content obtained.

Thus, the analysis of the interviews consisted of message comparison and classification operations. Categorization is the crucial step in this type of analysis, as it is defined as the process of classification of messages. In the case of this research, the categories were obtained following *a posteriori* method in both stakeholder and consumer interviews (Bardin, 2004).

Stakeholders' interviews analysis followed three *a posteriori* categories, that were created to capture stakeholder's knowledge regarding the generation of renewable energy by prosumers. Those are: (1) Consumer engagement: motivations; (2) Barriers to achieving renewable energy; (3) Generating renewable energy: The prosumer, drivers, and motivations.

Table 8: Stakeholders' interviews details

Participant name	Country	Occupation
Stakeholder 1 (S1)	UK	City Councillor
Stakeholder 2 (S2)	UK	Energy Entrepreneur and Consultant
Stakeholder 3 (S3)	UK	Analyst at an energy company
Stakeholder 4 (S4)	Germany	Employee at an energy company
Stakeholder 5 (S5)	Italy	President at an energy company
Stakeholder 6 (S6)	Spain	Project Manager in Energy
Stakeholder 7 (S7)	UK	Technical manager at Energy Systems

Note: Any personal information (name, age, etc.) was removed from the report to assure the following of GDPR guidelines and informed consent from TwinERGY participants.

Consumer engagement: motivations

The engagement and attitudes of consumers towards renewable energy are not homogeneous. Consumer groups and niches are built by different motivations and barriers. In general, stakeholders separate these groups into two: the first one is a niche built by early adopters, those motivated either by their passion for technology, government incentives, sustainability beliefs (referred by one of our experts as the "Tesla-people"), and or the second one, those that seek control of their energy expenditures ("energy savers", "budget-conscious consumers").

One important driver is environmental awareness. However, stakeholders consider this factor as not being isolated; that is, many drivers such as fiscal incentives need to be considered to reduce the gap between attitudes and real behavior. Thus, Stakeholder 2 (UK) mentioned:

> "*I think there is a large group of people that have now accepted that climate change is an important issue, and they feel early powerless to do much about it. It's a huge problem and they count too much and I think there's a very big attraction in demand*

response it's something they can do they can sign up for the service like this and feel they're doing something good for the environment so that can be a driver people care about their local community of nothing confident in many ways is reinforced that local resilience neighborhood doing something that supports local generation where I can point at a micro hydro scheme or a community wind farm" *(Stakeholder 2, UK)*

Besides green values being a strong driver for this consumer niche, stakeholders argue that it is not the only one as self-completion and fiscal reward motivations are relevant. Stakeholder 3 (UK) complements that:

"*historically there were a lot of environmental motivations the early adopters it was based on environmental motivations but nowadays it's fiscal*".

Competition and self-completion were also mentioned as key consumer drivers. In this way, a niche of consumers is motivated to demonstrate that they are doing something more significant, representing a self-completion by doing a good action for the planet or even as a competition between the local community. In this line, Stakeholder 2 (UK) posited that "*there are people that for various reasons will care about competing with their neighbors showing that they agree no engaged moral getting the badge for being the best in their neighborhood or the best in there play group*".

The second group is mentioned by the stakeholders as the end consumer sees energy as something practical, that is, he just wants to pay a fair price, and, whether or not he has control over his energy or sustainable energy. In this way, this group is considered by the stakeholders as the majority. Guided by the functionality of the energy, individuals from this group consider energy as something that must be practical and functional, convenient, and with fair prices. Stakeholder 2 (UK) reinforces consumers´ low involvement and convenience necessity by mentioning: "*I think for a lot of people they just want something they can sign up for and forget about it and they got plenty do with their-lives.*".

Thus, consumers seek little involvement and fair cost, and others who are more involved and seek energy control or even the production of their own energy. For instance, Stakeholder 2 (UK) explains that dynamic tariffs are a route to achieving renewable energy because it is a flexible way. However, it is not equally attractive to all consumers, considering their different limitations and motivations, as per the quote below.

Early adopters like to be the part of lightness thing, like to be in control of their energy, people engage to dynamic tariffs. This is one group. Large group that just want energy to work, feels that is expensive. Different people want different things so dynamic tariffs will work for some people helps to reduce the charge of them but having some

> *sort of tec is attractive. Equally achieve that giving the control completely to the energy company with a fair tariff. Two different routes to achieve that. More people easily and simplicity and a certain group would preferer more dynamic tariffs. By engaging in those tariffs those people can reduce and help to create a case for future generations.*" *(Stakeholder 2, UK)*

Barriers to achieve higher usage of renewable energy

The financial barrier is the most cited among all stakeholders. Stakeholder 1 (UK) argues that public policies and companies need to "*Reward consumers to see the value of this. For people that already can afford this, it will be even cheaper with government support.*" Thus, the cost of these technologies require new business models to achieve mainstream acceptance:

> "*...risks of exacerbating financially constrained consumers, how do we find business models that allow all consumers to benefit from this technology, not the consumer who already has an EV and solar panels etc.*" (*Stakeholder 1, UK*)

One way to overcome the financial burden would be to reward consumers, that is, using a direct reciprocity system. Thus, stakeholders explain that individuals will adopt it if they gain something back, especially savings. Thus, a big challenge for the future of renewable energy for the mainstream is "*How do we find the business model to bring the technology to those who cannot afford to it? (...) these services are offered in a niche place, not found in day-to-day services, energy services in the UK are not offering that as their core offers.*" (Stakeholder 1, UK). Thus, all stakeholders agree that without financial motivation, the mainstream consumers cannot see the advantages of payback for engaging in renewable energy.

Another relevant mentioned barrier is the lack of knowledge for the mainstream market. Stakeholder 1 highlights that those services are usually targeted for a niche market, but opens the possibility to spread for the big energy suppliers: "*What is already happening in the marketplace? The barrier is that those services are offered in a niche place but are not generally available. People don't hear about this. Big energy suppliers could offer this.*" Further, stakeholders complement that, more than education, consumers need convenience and to clearly see the advantages, as explained by S3 and S1 (UK).

> "*I don't really see a circumstance where you would need to educate a customer on grid capacity without that being a reason as in. I'm going to give you her manager management system to reduce grid capacity but you wouldn't just go to an end customer here's all you need to know about your local DSO grid capacity stricken streets. Yeah, they don't, even most customers don't even know who their DSOs are. They just sort distribution system operators.*" *(Stakeholder 3, UK)*

Besides the convenience of distribution, as being offered by big energy suppliers, our data also show that convenience to use is a challenge for achieving higher consumer engagement. Stakeholder 2 (UK) posits that "*it's still very early days does this not very wide adoption of home energy management concerning the UK and so it people still developing their propositions I think again a lot of it will be about convenience*". Interviewed 1 adds by mentioning the difficulty of many technologies: "*the process of implementing smart meters in consumers' houses (a lot of boxes and wires); people would care about keeping switched on a box that is linked to everything (heating, Wi-Fi,...), it should not be a secondary box*"
Considering this, stakeholders argue for the necessity of users' convenience, as informed by Stakeholder 2 (UK):

> "*Like I've got my car my heating system my hot water tank various white goods. If anything, that simplifies and gives me one place to sign up for service and then coordinate all that has to be attractive. I think there is a value driver in the sense that managing the home as an integrated portfolio can create more value than managing individual clients*"

Thus, a big challenge for the future of renewable energy is "*How do we find a business model to bring the technology to those who cannot afford to it?*". Consumers can be differently motivated to engage in renewable energy. According to Stakeholder 1 (UK), co-designing with companies and community engagement creates more legacy. That is, the co-creation of companies with the local community is necessary in order to empower communities to take a league.

Further, bringing the overall investment down is another important factor that can increase consumers' engagement in renewable energy. For the first interviewee, only a niche can afford, and Stakeholder 3 (UK) complements for a higher engagement and involvement, consumers need to realize which are the advantages for it.

> "*It would need something bigger like public policy or governmental incentives for people to adopt you. You look at the market development in Europe and the countries are doing better have the best fiscal policies you'll pay back time for a lot of batteries at the moment is still 10 years which is a long time yeah that*" (Stakeholder 3, UK)

Generating renewable energy: The prosumer, drivers, and motivations

Rising shares of fluctuating renewables increase the need for flexibility in the power market. At the same time, the emergence of the prosumer has created new opportunities for the co-creation of distributed flexibility. Prosumer is a new term coined to refer to the consumer that both produces and consumes the energy:

> "*For a lot of people, 'am I a prosumer or not' is not something they think about. People care about convenience. Being a prosumer is not the end goal for most people, they become a prosumer because it gets them somewhere.*" *(Stakeholder 4, GE).*

Energy is mainly accomplished through rooftop solar panels, heat pumps, and electric vehicles. Stakeholder 3 (UK) argued that:

> "*Ideally during sometimes you will buy energy from the from the network and another times where there are more demands he could actually sell by the same time that uses his own energy. In this moment, it's called a flexibility market where the consumer becomes a prosumer*".

The importance of consumer flexibility in order to build an energy network is reinforced by stakeholder 4 (GE):

> "*For our company is very important in the future use flexibility of the consumer so if a consumer hasn't strike system, so, if he can use his own energy that he gets from the roof, the future consumer will be a prosumer.*"

Thus, much effort needs to be made to a consumer who has a lot of flexibility and technologies to become a real prosumer. In this sense, stakeholders point to the challenges that the market is facing to boost the prosumer activity are: to produce and offer products like electric vehicles capable of doing that, achieve regulation flexibility adaption, and create engagement between consumers and the network and diminish financial barriers.

Furthermore, one challenge pointed by the stakeholders is the difficulty to become a prosumer in the city, compared to consumers who have a land of a house.

> "*We have a lot of prosumers and wind energy in Germany. The big problem, the main for the future is getting renewable energy in the big cities. I mean, in a land you can have a house. But the main problem is to rent small house or flat, you don't have the possibility to become a prosumer or producer of energy. People who rent a house they don't need to be a prosumer because they don't have advantage to do it. (Stakeholder 5, IT)*"

Stakeholder 4 (GE) reinforces the challenge to be a prosumer in big cities:

> "*In big cities you don't have the flexibility for being a prosumer. But the industry is a very big part, the industry is also producing energy. Aware of different targets, types of building to increase flexibility.*"

In a general way, stakeholders are optimistic regarding prosumer activity but mentioned that much effort from industry, policymakers, and the local community needs to be done. Regarding the financial reward, Stakeholder 4 explains that "*the regulations are tough to become a real flexible consumer or producer, but it's on the way I think in about 5 or 10 years the real consumer can be a producer or prosumer*".

Further, stakeholders acknowledge the lack of technology made available for the final consumer to be a prosumer, as stakeholder 5 explains:

> "*I don't think the big problem is that people don't want mobility. People would want to buy electric car and want to use it as energy storage for the own house, so they don't need to put energy storage to the house. Need for partners to storage station to load the car with energy and they are all in the development, this is the big problem, we don't know how expensive this could be. Only some cars have this possibility as Nissan, Mitsubishi and Honda, which can load and produce energy.*" *(Stakeholder 5, IT)*

The regulation of prosumers to enter the market, promoting guarantees are fundamental factors to be explored by the energy industry, as explained by stakeholder 5:

> "*A prosumer is somebody that produces energy and consumes it. But in, I would say, with a small percentage, with a small amount, and what we think it would be useful for consumers to have them enter in the market of energy exchange, of let me say, of asking and building of energy so what is called the energy market the daily energy market to help them become real player. But normally, when you have somebody who is selling energy to somebody else, might be a community, the neighbor, or even the market you often need guarantees*" *(Stakeholder 5, IT).*

Finally, stakeholders argue regarding the importance of prosumers recognition as players of sustainability promotion to engage the local community and promulgate the activity for new consumers:

> "*I believe sustainability should be recognized for that, what would mean, for example, to be getting rewarded for green energy, for the energy they produce from new sources, and give it to the community to the neighbor or to the provider so the driver*

(for energy sustainability) could be the fact of being recognized as an active player." (Stakeholder 5, IT).

In this sense, our data shows that green self-identity plays an essential driver for prosumer activity. However, it is not the only driver, as the players need to improve regulations flexibility adaptation where rewarding and flexibility could contribute to this sustainable activity.

7.2 Interviews with consumers

Research Procedures

Consumers were requested to answer different in-depth, open-ended questions in which they reported their drivers and barriers regarding their energy reduction, purchase of green energy, motivation to produce energy, and, finally, their attitudes regarding the future of sustainable energy. Participants were recruited online, and in-depth responses from the different target groups of the project were obtained. A total of 50 consumers from the United Kingdom (UK), Italy (IT), Greece (GR), Portugal (PT), and Germany (GE) participated. Please see Table 9 for further detail on the consumers' characterization.

Table 9 Consumers' characterization

Country	**Number of Participants**	**Average Age**	**Average people living in the household**
Germany	10	47	2.8
Greece	10	49	3.8
Italy	10	47	3.2
Portugal	10	44	2.9
United Kingdom	10	48	3.0
Gender	**Number of Participants**	**Average Age**	**Average people living in the household**
Female	20	48	3.1

Male	30	46	3.1
Country	**Number of Participants**	**Average Age**	**Average people living in the household**
Bachelor's degree	14	50	3.3
Doctorate degree	3	41	3.3
High school degree	15	46	3.2
Master or Postgraduate degree	15	45	2.8
Others	3	47	3.1
Occupation	**Number of Participants**	**Average Age**	**Average people living in the household**
Working (paid employee)	32	46	3.2
Working (self-employed)	5	45	2
Others	12	50	3.3

Seven *a priori* categories were created in order to capture consumers attitudes and behavior towards sustainable energy: (1) Energy Consumption Monitoring; (2) Motivations to reduce energy consumption; (3) Barriers to reducing energy consumption; (4) Achieving sustainable energy use and Generating energy at home: Attitudes to become a Prosumer; (5) Motivations to buy green energy; (6) Barriers to buying green energy, (7) The future of green electricity in Europe and the planet.

Energy Consumption Monitoring

More than half of the UK consumers reported having a smart meter for energy monitoring. Consumers also report having a safe energy awareness even without a smart meter, as reported by consumer UK1 "*We have a fixed price on our energy bills and a discount per month for dual fuel. We try to turn off appliances and lights when they are not in use*".

In Italy, Greece, and Portugal, consumers reported monitoring less energy, having no access to electronic meters. Instead, consumer PT2 informs that save energy by controlling energy consumption: "*I have nothing to control the energy, I have to avoid unnecessary energy expenditures, use low-energy light bulbs*".

German participants also reported controlling energy by comparing energy bills, controlling the energy consumption of not using devices, LED lamps, and low energy-consuming devices (AAA). Also, some German consumers reported having solar panels and a smart home system for energy management:

> *"We have solar panels on the rooftop and get a yearly payment of around 1,000 Euros/year, so if this would be considered, we do even make a profit regarding electricity, but I consider this a business. Monitor: only check arbitrary gauges measuring the consumption. After living six years in the house, I know the system well and to be stable. I use some high energy consuming devices (dish washer, washing machine) to a high extend only when I deplete energy from my solar panels (for free). LED light, low energy consuming devices installed in the house (A++ etc.). Some potential where I am not consequent such as chargers for the cell phones plugged all day but otherwise highly trimmed to save energy". (*GE5)

Our data showed a clear difference between Germany and the UK's energy consumption monitoring behavior compared with Italy, Greece, and Portugal. The first group, especially the UK, reported a higher level of consumption monitoring.

Consumer response	**Country**
We have a smart meter with a monitor. We regularly check this and I keep an eye on the values using an excel spreadsheet. UK1 *We have a fixed price on our energy bills and a discount per month for dual fuel. We try to turn off appliances and lights when they are not in use.UK8* *Yes, we have a smart display which was provided by our energy supplier. The display is placed in our living room for easy display, but we don't feel the need to constantly monitor it by app or anything. UK2*	*United Kingdom*

I replaced the old light bulbs with led lamps. I turn off the light every time I leave a room. IT6 *No, no control, I try to turn off possible things when I don't use them. IT4*	*Italy*
I'm trying to keep the energy consumption down by trying to use night charge (cheaper) as much as I can and I'm also trying to not have appliances and/or lights turned on if there is no use. Electricity in Greece is very expensive due to having extra charges (state tv channels + taxes + connectivity of mainland electrical network to islands and other) also keep an eye on the electricity meter to not surpass a certain amount of kwh because the cost scales with consumption. GR5 *I check the electricity meter from time to time. In addition I try to do my energy-intensive work during the zone of cheapest electricity consumption. GR7* *No external control. I try to be reasonable and use resources in a rational manner (e.g., turn off the light when I leave a room, do not use half full dishwasher etc). GR8*	*Greece*
We use the power meter and check it every 3-4 months. GE 4 *I manually control every month how high our energy consumption was. GE 3* *We have solar panels on the rooftop and get a yearly payment of around about 1,000 Euros/year, so if this would be considered, we do even make a profit regarding electricity, but I consider this a business. Monitor: only check arbitrary gauges measuring the consumption. After living six years in the house, I know the system well and to be stable. I use some high energy consuming devices (dish washer, washing machine) to a high extend only when I deplete energy from my solar panels (for free). LED light, low energy consuming devices installed inhouse (A++ etc.). Some potential where I am not consequent such as chargers for the cell phones plugged all day but otherwise highly trimmed to save energy. GE 5* *Yes, I do have. I only have energy-saving led light bulbs I have a smart home system using a fritz router. I have connected an AVM FRITZ!DECT 301 temperature control device to the Fritz router. I have a weekly and daily plan in the router that controls the temperature in the radiator. I have four smart plugs that measure the energy consumption of my computer and my tv, and other devices. The devices can be turned on and of by Amazon Alexa and mir Fire home devices. From time to time, I control the total energy consumption on the electric meter in the cellar. GE 2*	*Germany*

Just by analyzing the bill and the counter PT1 *I have nothing to control the energy, I have to avoid unnecessary energy expenditures, use low-energy light bulbs and buy class A household appliances. PT3*	*Portugal*

Motivations to reduce energy consumption

In general, consumers' primary motivation to reduce energy consumption is in the first place to save money. Consumers reported that energy is currently very expensive and have this control in order to reduce the month's expenses.

> *"Saving money is the primary target. Secondary conserving environment but mainly because my energy is already green electricity (for heating my consumption cannot be influenced to a high extend house is constructed in 2014 and matching all German laws regarding heat preservation". (GE4)*

> *"Reduce the cost as it is too expensive". (UK3)*

> *"To save money. To reduce the costs of energy bills. Also, to put less of a strain on the environment by consuming as little energy as possible that is produced by fossil fuels like coal and others". (GE5)*

> *"Saving money, and maybe also an environmental related reason too". (IT3)*

The second motivation to save energy is environmental awareness. Most of the consumers appear to be conscious that energy-saving is associated with sustainable actions and that this is a way to help with climate change and global warming. This notion of self-efficacy is important and can be further developed by policymakers to increase consumer engagement with energy-saving:

> *"It will be for environmental reasons. As I have mentioned earlier, we don't have any problem with income and have more than enough disposable income. So, there is no need for us to be strict with our spending". (UK2)*

> *"Doing my bit to reduce energy consumption and fight against global warming/ climate change. keeping the earth as a safe inhabitable planet for future generations". (GR1)*

"Decrease in Co2 emissions". (PT2)

Consumer response	**Country**
It will be for environmental reasons. As I have mentioned earlier, we don't have any problem with income and have more than enough disposable income. So, there is no need for us to be strict with our spending. UK2 *Reduce the cost as it is too expensive. UK3*	*United Kingdom*
Saving money, and maybe also an environmental related reason too. IT3 *High cost of energy. IT7* *Efficiency, save money, environment. IT10*	*Italy*
Doing my bit to reduce energy consumption and fight against global warming/ climate change. Keeping the earth as a safe inhabitable planet for future generations. GR1 *Participate in some alternative community with people who actually reflect on their choices and energy consumption; 2. Know that my behavior would actually bring about change on a small-scale level; 3. Monetary incentives. GR4* *The main motivation would be to pay less. GR2* *Environmental reasons, moral reasons, monetary reasons. GR3*	*Greece*
Saving money is the primary target. Secondary conserving environment but mainly because my energy is already green electricity (for heating my consumption cannot be influenced to a high extend house is constructed in 2014 and matching all German laws regarding heat preservation. Refurbishment makes no sense. GE4 *To save money. To reduce the costs of energy bills. Also, to put less of a strain on the environment by consuming as little energy as possible that is produced by fossil fuels like coal and other. GE5*	*Germany*

To be frank, I want to save my money. I hate to waste it - but you can't separate this "mundane" motivation from other aims - because at the same time it is good for the environment. GE8 *Saving money is the primary target. Secondary conserving environment but mainly because my energy is already green electricity (for heating my consumption can not be influenced to a high extend house is constructed in 2014 and matching all German laws regarding heat preservation. GE10*	
Energy provider should help customers to obtain clean energy as solar panels or home wind turbines free of cost. PT2 *Firstly, monetary and sustainability conscience PT3* *Decrease in co2 emissions PT2*	*Portugal*

Barriers to reducing energy consumption

The barriers mentioned by consumers are entirely associated with the barriers considered by the interviewed stakeholders. For instance, the most significant barrier pointed out is the investment cost, as mentioned by consumers:

> *"if I had much money, I would buy solar panels, a little bit of laziness in the beginning (smart home is not funny in the beginning), lack of smart home technical providers, relatively high prices for smart home devices, lack of alternatives since it is not my house". (GR4)*

> *"The effort to reach the next improvement level requires high investment (i.e., battery for solar energy to be more independent to external delivery). Lowering heat energy with three little kids would imply loss of comfort/living quality". (GE3)*

Further, consumers also reported the lack of time for monitoring and the technology usability, as, for instance, the limited choice when individuals need to rely on landlord rules.

> *"Family and work-life take too much of our mental resources. I don't think I will have the energy to constantly monitor the behavior of all family members to save energy. The reward scheme is nonexistent, for instance, if we manage to save, we should have been rewarded not only by cheaper energy, perhaps also by giving us some kind of green points". (UK3)*

"The cost for changing energy production systems (like the switch to solar power system)". (IT3)

"Limited choice as a home renter. Working from home and being home most of the time". (UK3)

For Italians, Portuguese and Greek consumers, the most mentioned barrier is the cost to buy new devices and the lack of motivation for it. For instance, consumers mentioned the lack of involvement with energy-saving:

*"Comfort, the laziness of not saving energy as a barrier". (*PT3)

"I don't care too much, I don't have the time to think about it". (IT7)

Participants also reported that the considered barriers are the effort to reach an energy consumption improvement, lack of convenience, and the effort required considering other priorities. Data protection from energy monitoring was also pointed as a barrier, as mentioned by consumer GR10: "*Convenience, Data protection.*"

Consumer response	**Country**
1. Cost. 2. Time 3. Landlord restrictions. UK1 *Limited choice as a home renter. Working from home and being home most of the time. UK2* *We are somewhat limited as we do not own our house we rent it, so we cannot make the required modifications that we would like to such as fitting solar panels etc. UK7* *Replacing electrics. UK5* *Family and work-life take too much of our mental resources, I don't think I will have the energy to constantly monitor the behavior of all family members to save energy. The reward scheme is nonexistent, for instance, if we manage to save, we should have been rewarded not only by cheaper energy, perhaps also by giving us some kind of green points. UK3* *If we were to be given grants to help with the cost from the government or if our landlord would fit solar panels on the roof. UK10*	*United Kingdom*

The cost for changing energy production systems (like the switch to solar power system). IT3 *I don't care too much, I don't have the time to think about it. IT7*	*Italy*
Convenience, Data protection. GR10 *Maintain a certain quality of life, a lack of possibilities to save more energy. GR1* *if I had much money, I would buy solar panels, a little bit of laziness in the beginning (smart home is not funny in the beginning), lack of smart home technical providers, relatively high prices for smart home devices, lack of alternatives since it is not my house. GR4*	*Greece*
The effort to reach the next improvement level requires high investment (i.e., battery for solar energy to be more independent to external delivery), lowering heat energy with three little kids would imply loss of comfort/living quality. GE3 *No smart home to help manage energy consumption. High desire for energy consumption for entertainment purposes like TVs or music or similar. Forgetting to turn off unneeded devices or lights. GE2*	*Germany*
Confort, laziness PT3 *high consumption devices PT1*	*Portugal*

Achieving sustainable energy use and generating energy at home: Attitudes to become a prosumer

The majority of UK consumers indicated solar panels as the way to achieve sustainable energy use. However, some barriers were pointed to as government regulations, lack of information and communication from energy players, cost, and renting. Further, consumers from the UK reported the difficulty of putting the production in practice as it involves a high initial cost. However, most participants explain that overcoming some barriers is possible.

> *"Generating sustainable energy at home would be great, e,g. using a solar panel or the latest technology (boiler heating something, land based heating?). However, I need to know the cost and the chance of failure and also the longevity of the technology involved. If this kind of*

programme is supported by government (and guaranteed in some way), then I will be more convinced to take it up. Obstacles would be cost and also regulation of the provider that would help me implement it. There are a lot of "rogue" traders or companies, and they need to be regulated properly". (UK2)

"If we were to be given grants to help with the cost from the government or if our landlord would fit solar panels on the roof". (UK1)

The same goes for German consumers, which reported a positive attitude to engage in energy generation, like hydropower, wind energy, solar energy, affirming that it is not uncomfortable and possible. However, most believe that regarding the cost to engage, there is common laziness to remain in a "well-established situation". Further, consumers face the barrier of not being feasible to generate energy due to their renting house conditions, as mentioned by consumer GE3:

"Hydro power, wind energy, solar energy - if I had my own house where I could do what I really want, I certainly would use solar energy. No, I don't think it is uncomfortable - it is more a kind of common laziness not to be willing to think over an already "well established situation" and to change it". (GE3)

Italians and Portuguese consumers mentioned that to achieve sustainability in energy use, they would need more information from the government and the energy providers. Consumers also reported having positive attitudes to prosumer activities, especially regarding the adoption of solar panels. However, the cost is still high for the engagement of end users as prosumers.

"I would love community-based energy production, I have considered producing my own electricity but it is not affordable for me at the moment". (IT5)

"Government should give us new eco-friendly home appliances for free, and in this way, we could save money and energy for the planet and for our wallet". (IT3)

"Is fundamental that generating sustainable energy at home become more accessible to everyone. living in an apartment is a big obstacle for implementing it and the price is still too high". (PT8)

Greece consumers report being more skeptical about the prosumer activity, stating that they do not have much needed information, problems with the initial cost, and need for governmental help.

> *"(...) You can use a bike instead of a car, for instance, but everything you buy comes from a big supermarket in the other part of the world, I do not think you make a substantial change.*
>
> *Things are perhaps worse in Greece as the public is not educated, respectively and people are insensitive towards sustainability issues. The lack or problematic function of respective services e.g., recycling or public transport, makes things even worse. That is (moving to your second question) in Greece, relative to north European countries, it is definitely harder to engage in sustainable energy behaviors". (GR1)*

Consumer response	**Country**
It is in practice feasible to have sufficient space to put in solar panels or a small windmill. However, as mentioned, the intel cost is prohibitive, with the cost being £8000-10000 with a long payback on the equipment. UK8 *Would love to… I can't afford a high initial investment. UK4* *I think initially implementing your home to be more energy efficient is really quite costly and as the house is not ours we are somewhat against spending so much money on a property that isn't ours so its a bit of a catch 22. UK7* *Generating sustainable energy at home would be great, e,g. using solar panel or latest technology (boiler heating something, land based heating?). However, I need to know the cost and the chance of failure and also the longevity of the technology involved. If this kind of programme is supported by government (and guaranteed in some way), then I will be more convinced to take it up. Obstacles would be cost and also regulation of the provider that would help me implement it. There are a lot of "rogue" traders or companies, and they need to be regulated properly. UK2* *I would like solar panels but energy usage is too low to qualify. Should not be uncomfortable. UK1*	*United Kingdom*

I don't think it's uncomfortable but it's often not easy to retrofit into an older property. Our house is not ideally situated for solar panels and we have little space for the equipment needed for solar-voltaic. We cannot afford a ground source heat pump. UK6 *If we were to be given grants to help with the cost from the government or if our landlord would fit solar panels on the roof. UK3*	
I would love to! But the starting setup costs are not affordable for me at the moment. IT7 *I would try to use solar cells for fueling desk lamps or something similar. I'm unable to think of other opportunities. They are not so common and still quite expensive here. IT2* *I never thought of producing energy for others. I know solar panels, I know that they are very expensive but I haven't really known that I could produce energy for others. IT8* *I would love community-based energy production, I have considered producing my own electricity but it is not affordable for me at the moment. IT5* *Government should give us new eco-friendly home appliances for free, and in this way we could save money and energy for the planet and for our wallet. IT3* *I think that in our country, the matter of sustainable energy is not enough publicized. IT1*	*Italy*
No, is not uncomfortable to engage but the state isn't helpful at all to achieve sustainability. Greece is bathed with sun and quite windy, so it's quite easy to create electricity from those sources but there is no (or too little) will from the state to give reasons for this to grow. GR10 *I could install photovoltaic panels if I did not have financial difficulty in it.* *I think it would be relatively inconvenient at first until the new mindset is changed and installed. GR7* *That is to have a lifestyle that is sustainable in a broader way, a more independent lifestyle in a rural area, where I consume mainly things I produce, alone, or even better as a part of a group with which we share similar views and values. Currently, I try to reduce consumption and be highly skeptical on what I buy, what I eat what I throw etc. But everything is intertwined, I think. You can use a bike instead of a car, for instance, but everything you buy comes from a big supermarket from the other part of the world, I do not think you make a substantial change.Things are perhaps worse in Greece as the public is not educated respectively and people are insensitive towards sustainability issues. The lack or problematic function of respective services e.g., recycling or public transport, makes*	*Greece*

things even worse. That is (moving to your second question) in Greece, relative to north European countries, it is definitely harder to engage in sustainable energy behaviors. GR1	
Not at all, if you are willing to pay a little. I receive my electricity from a certified sustainable energy provider (Greenpeace Energy). For heating, it is more problematic as it is used for the whole house (not only for my flat) and powered by gas. GE1 *Hydro power, wind energy, solar energy, - if I had my own house where I could do what I really want I certainly would use solar energy. No, I don't think it is uncomfortable - it is more a kind of common laziness not to be willing to think over an already "well established situation" and to change it. GE4* *No it's not uncomfortable. Installing solar panels on the roof for one would be a step in the right direction. But it's not cheap. Also signing up for a new energy contract with an energy producing company with at least 100% eco produced energy. But also not cheap. Installing or converting your home into a smart home is also a step in the right direction. A smart home can manage and save energy. GE2*	*Germany*
Our electrical supply uses more than 60% of sustainable energy but living in an apartment, it is not suitable to have solar panels PT1 *Not it all, our government should support it and energy bills should be cheaper for all PT3* *Have energy production on site with free and renewable sources like wind and solar power. The downside is the regulations that restrict what can be done and also the investments needed to implement such things for the average citizen PT6* *Is fundamental that generating sustainable energy at home become more accessible to everyone. living in an apartment is a big obstacle for implementing it and the price is still too high PT8* *We could, but for solar panels we'd loose much space in the balcony, plus it might be difficult to know where to store all the electrical appliances for that. PT10*	*Portugal*

Motivations to buying green energy

Regarding consumers' motivations toward green energy adherence, participants mainly reported to be motivated by financial savings and that they would engage in green energy If they could afford it. For instance, some participants mentioned the importance of governmental support in order to cover the implementation costs:

> *"The benefit should outweigh the current approach. The benefit could cover cost, implementation cost, reliability as well as other incentives given by the government to do so. I have never had any conversation about buying green electricity, but more of green technology to generate heating for the house". (UK2)*

Consumers in Italy and Greece are motivated in order to save energy and money. However, it is necessary to increase their perception of reliability in green energy, the infrastructure, energy policies, and more diversity of players in the energy market:

> *"I might be motivated by the lower cost of energy." (IT1)*

> *"The presence of adequate infrastructures". (IT6)*

> *"Green energy should not be developed at the expense of household finances, so any financial support would help a lot. No, I haven't had any conversation about buying green electricity". (GR10)*

> *"I have had conversations about buying green electricity, but I don't believe it is real green". (IT7)*

Portuguese consumers appear to have low involvement with green energy production. Few participants reported being motivated in engaging with a low cost, as mentioned by consumer PT3; however, the prosumer activity in Portugal is still not known by consumers: "*I would be open to it, if I could afford it. Never had any serious conversation about that". PT3*

The United Kingdom and German consumers reported to be already familiar with buying green energy. However, some argue that the implementation cost, and the type of house, like a rented house, are important barriers.

> *"I am already buying green electricity. If the price difference to conventional energy would be lower (e.g., through subventions), maybe more customers would change to green electricity". (GE2)*

Consumer response	**Country**
If it was offered by a reliable supplier UK10 *We already do buy green electricity UK5*	*United Kingdom*

The house needs to be equipped with more energy efficient appliances and better insulation in the loft etc but this is not something that the landlord is willing to do. Owning our own home would definitely motivate us as we would see it as more of an investment into our future than into someone else's future UK3 *The benefit should outweigh the current approach. The benefit could cover the cost, implementation cost, reliability as well as other incentives given by the government to do so. I have never had any conversation about buying green electricity, but more of green technology to generate heating for the house. UK2* *I am already interested, I have never talked about it with my family. UK1*	
Saving a lot of money would be a great motivation towards using green electricity, but there are few providers in my country. I was never contacted or I never contacted any of them so far. IT3 *I might be motivated by the lower cost of energy IT1* *The presence of adequate infrastructures IT6* *In Italy there aren't companies selling green electricity. IT2* *I have had conversations about buying green electricity, but I don't believe it is really green. IT7*	*Italy*
It's all about cost. I wouldn't give 1 cent more to buy green electricity. I have never had this conversation because I don't think the cost allows me to consider it. GR2 *Green energy should not be developed at the expense of household finances, so any financial support would help a lot. No, I haven't had any conversation about buying green electricity. GR10* *To actually believe that green electricity is actually "green". One can not exclude the economic interests related to the modernization of energy policies, especially in corrupted countries. In Greece for instance, the last two governments have decided to implement policies towards green electricity production by initiating wind parks all over Greece. That is 25300 wind turbines imported from foreign multinational companies to be put all over Greece destroying many sensitive ecosystems and disorganizing completely local economies. This, without taking into consideration the resistance of local communities towards such ideas, the lack of planning and the very rapid, obscure and disorganized way of making public auctions and allocating such enterprises to foreign companies that are mainly interested in profit. Even more, all this happens while the same governments have, at the same time, authorized major petroleum companies to extract oil and gas from the*	*Greece*

sea, again in areas that have been characterized natura2000. Such controversies do hurt the belief that green policies are actually pro environmental. Thus, to answer personally, reasons like the aforementioned result in my reservation to buy green electricity. GR1	
What would motivate me would be a cost reduction in the price. Like a certain discount in signing up for a green energy contract. In other words I would buy green energy but for a cheaper price then other energy producing sources GE3 *I am already buying green electricity. If the price difference to conventional energy would be lower (e.g., through subventions), maybe more customers would change to green electricity. GE2*	*Germany*
I would be open to it, if I could afford it. I never had any serious conversation about that. PT3 *I've never had conversations about it but if the price is the same as the other energy sources, then it would be a good motivation. PT10* *If I didn't have the money barrier, there would be no problem PT4*	*Portugal*

Barriers to buy green energy

The majority of the consumers mentioned the cost of green energy compared with conventional one as the bigger barrier. In general, the cost and the lack of information are the biggest barriers, especially for Italians, Germans, and Greek consumers. Thus, as mentioned in the last section, the majority of consumers consider green energy production as being costly. Consumers need to perceive economic advantages in order to engage in the prosumer activity.

> *"The only barrier is if it's much more expensive than normal electricity. I have never been approached to buy green electricity". (UK2)*
>
> *"In most cases, it is more expensive than conventional electricity. Nobody encouraged me in regards to that yet". (GE1)*
>
> *"Apart from the price, I see no other barriers". (PT5)*

Further, consumers reported the need for more variability and reliable providers, financial barriers, lack of knowledge. The lack of information is also important as few consumers mentioned not being aware of government and private programs towards green energy.

"Reliability of technology and cost. I have an impression that everything that is green will be more costly than as is. if we were given something to offset this, then perhaps going green would make more sense. I have never discussed this, so no one has encouraged or opposed the idea. However, the analogy of green electricity is an electric-based car. Which again, I am hesitating to buy due to the cost and reliability of the technology itself (charging facility, limitation of range, etc.)". (UK7)

Other barriers mentioned are bureaucracy and the difficulty to reach an agreement between stakeholders. As reported by the consumers:

"The initial cost of installation and the impossibility of reaching an agreement with all the people involved". (IT6)

"Cost of implementation and bureaucratic difficulty from the state. I had the idea opposed by a relative that bought and implemented such technology and had little gains". (GR2)

Consumer response	**Country**
More green energy providers would be great.... I haven't heard anybody opposed to this idea UK9 *Reliability of technology and cost. I have an impression that everything that is green will be more costly than as is. If we were given something to offset this, then perhaps going green would make more sense. I have never discussed this, so no one has encouraged or opposed the idea. However, the analogy of green electricity is electric based car. Which again, I am hesitating to buy due to the cost and reliability of technology itself (charging facility, limitation of range, etc.) UK7* *The only barrier is if it's much more expensive than normal electricity. I have never been approached to buy green electricity. UK2*	*United Kingdom*
For me, the barrier is the cost compared to traditional electricity. I can't afford an increase in the expenses for the household at the moment. I had a discussion with family and friends about this topic and some are pro-green electricity and some believe that it is pointless IT3 *The initial cost of installation, the impossibility of reaching an agreement with all the people involved IT6*	*Italy*

There is insufficient information on the possibilities and necessary steps for the green energy market. At least I have not been informed. GR7 *Cost of implementation and bureaucratic difficulty from the state. I had the idea opposed by a relative that bought and implemented such technology and had little gains. GR2*	*Greece*
In most cases, it is more expensive than conventional electricity. Nobody encouraged me in regards to that yet. GE1 *I got some promotions from the Deutsche Bundesbahn and other offers. I would have got extra points for my railway card as "motivation" and a bonus. My father has "green" electricity since this town has a hydro power plant that gives as far as I know power for the whole city - and they are even quite cheap. GE2*	*Germany*
I don't have much knowledge about green energy and never talked with anyone about it PT3 *Apart from the price I see no other barriers. PT5*	*Portugal*

The future of green electricity in Europe and the Planet

When asked about the future of green electricity and if they can be part of it, the majority of the consumers provided a favorable response. Positive attitudes and the given importance of green electricity as a way to achieve sustainability were also highlighted.

Our data also show that consumers are motivated and be part of a green future, as reported by the following consumers. More than that, some consumers also reported a sense of responsibility regarding the environment.

> *"I think everyone can be part of it, whether that be by reducing their own carbon footprint or something as simple as switching lights off in a room when they leave it. I think it's everyone's responsibility". (UK10)*

> *"I believe that green energy is a necessary measure to deal with the destruction of our planet. Europe has taken initial steps mainly in terms of the use of electric cars, but I do not know if this is the use of green energy ... More and more drastic measures need to be taken with the mandatory participation of all European citizens". (GR5)*

Consumers are motivated to engage in green energy, pointing out some changes that would be necessary to achieve this goal, for instance, by changing governmental incentives and providing affordable green energy.

> *"Government could provide some incentives to increase private investment in this area... I am optimistic that more and more people would demand the government to take action in the next decade". (UK8)*
>
> *"I believe that green energy is a necessary measure to deal with the destruction of our planet. Europe has taken initial steps mainly in terms of the use of electric cars, but I do not know if this is the use of green energy ...More and more drastic measures need to be taken with the mandatory participation of all European citizens". (GR5)*
>
> *"I see green electricity as the future of power in the UK. I would love for micro-generation to be more affordable". (UK2)*

In general, consumers from the United Kingdom and Germany believe that the future of sustainability has already arrived in their countries, as wind and solar production is growing. For instance, consumer UK5 reported that: "*It will only increase. The UK has a lot of wind farms and many houses have solar panels. If they can offer subsidies based on something other than your perceived income, I would certainly contribute but simply cannot afford to be any more proactive.*" *(UK5).*

Consumer response	**Country**
I see green electricity as the future of power in the UK. I would love for micro-generation to be more affordable UK2 *It will only increase. The UK has a lot of wind farms and many houses have solar panels. If they can offer subsidies based on something other than your perceived income, I would certainly contribute but simply cannot afford to be any more proactive. UK5* *I think everyone can be part of it, whether that be by reducing their own carbon footprint or something as simple as switching lights off in a room when they leave it. I think it's everyone's responsibility UK10* *I think this will still be a long way. Although eventually, we will get there. When cost is offset and enough incentives are given to go for green electricity then it will happen. It just*	*United Kingdom*

needs enough mass to make it more affordable. Yes, I can see myself being part of it once it becomes more or less the norm and the technology is proven. UK7 *Government could provide some incentives to increase private investment in this area..... I am optimistic that more and more people would demand the government to take action in the next decade UK8*	
I feel like Northern Europe is much more ready for green electricity. I would like to be part of it, perhaps starting from some small appliances, to begin with. IT1 *Sure I can but governments must help it. Electric cars, eco-friendly homes: everything is possible but the single 'small' private person can't make big things: why don't governments help us with bonuses at zero cost? IT2* *I was slowly getting closer to using more and more. I hope they invent ways of changing things in general – the change has to be general and not personal IT10* *It's the future.!!!! If we don't change the electricity to green electricity the atmosphere will get much worse than it is now. I definitely want to be part of it, but I am afraid that I can't afford it. IT11*	*Italy*
It's a one way road. Sooner or later, green electricity will be the main productive force of electricity. I want to be a part of it but only if it greatly benefits my wallet. (I know the impact to the environment is huge by using fossils and a major issue for the environment but if you cannot afford something then you cannot have it) GR4 *If there is no independent authority both in Europe and globally regarding the issue, I think it's really hard to implement actual policies that promote green electricity without having a negative consequence on another environmental factor. The issue requires extended and transparent public discourse where all stakeholders can participate, taking into consideration many factors both social and environmental, under such circumstances I could be part of it. How.... by contributing both with ideas as well as with ky daily practices and engagement GR7* *I believe that green energy is a necessary measure to deal with the destruction of our planet. Europe has taken initial steps mainly in terms of the use of electric cars, but I do not know if this is the use of green energy ...More and more drastic measures need to be taken with the mandatory participation of all European citizens. GR5*	*Greece*

Many European countries are moving to more green electricity, the problem is to convince poorer countries to act. Cooperation's between richer and poorer countries are needed. I can be part of it by giving a good example. GE1 *We are part of it in Germany. In a very short time there will be no more nuclear power plants. There is more and more wind and solar energy. I am very optimistic. I can save energy - that is what I do. Maybe I will change to "green" electricity if somebody convinces me that this is not a fake and something "virtual" only on my bill from my electricity supplier - without any control. GE2* *I can be part of it in future but it depends on the costs. Energy companies should see to it that they reduce the average costs of electricity for consumers. Green electricity in Europe has a long way to go, in my opinion. Most energy companies in Europe are still using fossil fuels like coal and delay modern electricity production for as long as possible unless they raise prices for consumers out of greed. Similar to oil producing companies. Green electricity is a good thing for the world and I still have hope for the future. It is very much possible to have only green energy around the globe. But it will take a long time since certain greedy companies are delaying it as much as possible GE4* *It is 'luckily' still considering the future in Germany. My country's electricity supply is still becoming greener every year. The main thing one can do to facilitate it is to vote for parties that support more ambitious climate targets. GE10*	*Germany*
I see Europe more and more aware of sustainable energy sources. I have no idea how I can be a part of it. PT3 *I feel I'm not in a position to do something really meaningful. Probably green electricity Will be the future but only when the economic powers decide so. PT5*	*Portugal*

Increasing consumer engagement in demand response programs

Consumers, in general, believe that government and public actors need to provide more relevant and targeted information to motivate and engage the local community. As reported by consumer one from UK:

> *"To become more mainstream, less of a niche reliability and clear cost-benefit. heavily regulated process to avoid "conning" people due to unfamiliarity of technology. A lot of incentives are given to take up the technology". (UK1)*

Further, in their opinion, energy policies should be transformed to attend to the mainstream public's interests. For instance, the participants argue that governments could subside green energy, reducing its price.

> *"I think Governments should invest in lowering the costs of the technology for the self- production of electricity make it more affordable so more families can be self-sufficient". (IT5)*

Overall, our data show that participants are optimistic regarding the future of green energy:

> *"I am very optimistic about this issue. However, this is a slow process that involves all countries on the planet in order to converge in the production of clean and self-sustainable energies. It involves social, economic and environmental and other issues". (PT3)*

However, few consumers reported being pessimistic mainly due to the major change needed in energy policies and other government efforts, such as informed by consumer IT7: "*I am not optimistic about because this requires a 180° change in energy policies and geopolitics.*"

Consumer response	**Country**
To become more mainstream, less of a niche reliability and clear cost benefit. heavily regulated process to avoid "conning" people due to unfamiliarity of technology. A lot of incentives given to take up the technology. (UK, 1) *Price, help from government, easy access. (UK, 4)* *Again just more information available to the general public which would create greater motivation (UK,6)* *More encouragement to implement retrofitted solutions. MUCH more efficient government grants/help. At present they are a pain for the householder and often lead to exploitation by shady contractors - and less participation by honest and efficient contractors. They actually do little other than push the price up (UK, 10)* *Yes, there are a lot of it, I guess. Over reliance in gas-based energy source as well as the unclarity of government programs when it comes to green electricity (such as solar panel installation). the program only lasts a few years, and I read in the news that the programme has ceased now. Also, some bad news about people being conned about solar panel installation. (UK, 7)*	*United Kingdom*

A greater public awareness campaign.(IT, 1) *I think Governments should invest in lowering the costs of the technology for the self-production of electricity to make it more affordable so more families can be self-sufficient. (IT, 5)* *I am not optimistic because this requires a 180° change in energy policies and geopolitics. (IT, 7)*	*Italy*
The optimistic scenario is that green energy will become very cheap, even free for everyone to use without cost. However, the pessimistic scenario is that cheap energy will be abused with a negative impact on the environment (a quick thought is the abusive use of a/c or heating and the impact on the climate). (GR, 2) *Optimistic, that the government's educate citizens to make informed decisions. It is not simply nudging them with a benevolent paternalism towards, apparently, right attitudes and behaviors. Of course, this requires that governments are independent of certain economic and political think tanks, which I think is rather difficult to happen. (GR, 3)* *Pessimistic, things continue as they go until some really crucial point, where again bad decisions are made due to a lack not of resourcefulness but of actual willingness to face the problem and the contributing factors with a bold eye. (GR, 5)* *I believe that countries must subside the use of green energy and help people to change. They must also obligate large companies to change their electricity to green or to pay more taxes. The car industry must also manufacture more electric cars. Children must learn the advantages of green electricity at school and get used to it. (GR, 6)* *Education. Connection with the problem in a personal manner and not with abstract ideas. Perhaps, personal engagement and motivation with monetary and social incentives as a short-term way of dealing with it until the long-term solutions can be more effective. (GR, 7)*	*Greece*
I think it largely depends on political decisions and on how much people will understand the impact of climate change. I am somewhat optimistic that change might be possible, at least in Germany. (GE, 4) *Install more wind turbines and solar panels where possible. The state should force this with subventions and raise taxes on non-green energy. Generally, I am slightly more optimistic than pessimistic here. (GE, 5)*	*Germany*

It is simply what we are already doing in Germany - wind energy - solar energy. But there should be done much more. But hydrogen is also a very good, underestimated power source for instance for cars. There should be a much greater national and international effort. The Corona crisis has shown that there is endless money available if we just want to. With a fraction of the money we all spent against we could have fulfilled many dreams of climate activists. This might be the optimistic view. But maybe it is simply already too late - since Europe and Germany cannot save the world if there is not a common worldwide effort even in the "rising" countries in the so called third. From a technical point of view, I am optimistic. From the "social" point of view, I think we will fail. (GE, 7) *We need more local networks and more long-distance exchange concepts. I think the old "wires" will need high investment to compensate for future fluctuations. But manageable. It will come, latest when globally nuclear power plants become less attractive. They are still maybe a necessary stable backbone (if you do not want to rely on coal, natural gas for backup) (GE, 9)* *The people should be more informed from politics etc. how important this topic is for the future. (GE, 10)*	
The solutions are spreading in the big industry. I think that is less spread at-home production. (PT, 6) *I'm a pessimist. The solutions, in my opinion, would make major changes in our society. And major changes would mean major losses to some powerful entities. That is the main barrier to the so needed changes. (PT, 2)* *I am very optimistic about this issue, however, this is a slow process that involves all countries on the planet in order to converge in the production of clean and self-sustainable energies. It involves social, economic and environmental and other issues. (PT, 3)*	*Portugal*

7.3 Concluding Remarks

The qualitative interviews have achieved the main goals of (1) understanding participants' attitudes regarding green energy engagement and (2) clarifying which are the barriers and drivers for energy-saving and green energy production. Our data showed that, although we follow a semi-open method of collecting interviews, there is an essential alignment in the information provided by both stakeholders and consumers.

This alignment reflects the importance of our data as a reflection of the green energy industry. For example, most stakeholders reported that they currently consider two consumer audiences to be reached through different strategies, when it comes to engaging in green energy. The first group is considered a niche market that, depending on the country, is becoming mainstream. This massive consumer market is overall concerned with the environment and its consequences on the planet. It prefers an engagement with energy-savings and is often in the role of prosumer producing energy for their home and the local community. The majority of this group has greater financial power and has overcome the barriers mentioned above related to the costs of implementation, type of property and lack of government incentives. Moreover, this group is usually connected with technology and has the motivation to be green energy pioneers in the control of energy expenditures or in the production of clean energy.

The second consumer group is considered the mainstream by stakeholders. As seen in consumer interviews, they would be motivated to have a higher engagement with green energy if it could be cheaper and provide higher benefits when compared with conventional energy.

In this way, some motivations pointed by consumers and stakeholders are essential in order to understand how the industry and policymakers could reduce the gap between attitudes and real behavior. That is, the engagement with sustainable energy would be higher If financial costs could be diminished, mainly through the increase of government investments in clean energy, diminishing costs of adherence, and making it more practical to consumers. Further, consumers also reported their necessity to perceive reliability in clean energy and energy providers, the necessity to receive more information regarding green energy benefits, and the reduction of bureaucracy. As also mentioned by the stakeholders, the difficulty in adhering to green energy also occurs through the type of housing. In other words, consumers who are in the countryside have more ease of adoption, as well as house owners. The interviews also illustrate that the minority of consumers interviewed are guided purely by sustainable reasons. Most consumers reported being led for financial purposes, both in terms of energy-savings and engagement with clean energy production.

Regarding participant's attitudes toward the future of energy, it can be inferred that most consumers and stakeholders see green energy as the future of the industry. The reduction of the environmental consequences caused by conventional energies by increasing the production and consumption of green energy, is seen mainly as the responsibility of the government. However, consumers assume that they would like to be part of it. If the cost barrier could be mitigated and effectively addressed. In other words, our data shows that all consumers are predisposed to engage in energy-saving and green energy production. However, our data show that the gap between attitudes and real behavior must still be bridged; that is, if the costs are less than the benefits, consumers would be motivated to engage in green energy pursuits.

Besides the financial cost barrier, policymakers and stakeholders could motivate consumers to engage in green energy by educating and creating environmental awareness. Thus, communication needs to be developed by creating reliability and connection between green energy providers and consumers, increasing local community involvement, and decreasing the effort to adhere.

In conclusion, the results of the interviews highlighted the importance of education and provided rich content of information about some specific KPIs, that were mainly mentioned by consumers and stakeholders. Those are prosumer empowerment, prosumer engagement in local energy trading markets, active participation rate through user engagement and acceptance, minimization of energy costs for the end-user, increased satisfaction and social benefits, and customer responsiveness.

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