D2.4 | High-level requirements for the ENPOWER technological, social and business framework

DST

May 2024

This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement Nº 101096354

Energy Activated Citizens and Data-Driven Energy-Secure Communities for a Consumer-Centric Energy System

Grant Agreement Number	101096354	Acronym	ENPOWER
Full Title	Energy Activated Citizens and Data-Driven Energy-Secure Communities for a Consumer-Centric Energy System		
Topic	HORIZON-CL5-2022-D3-01: Sustainable, secure, and competitive energy supply		
Funding scheme	HORIZON Innovation Actions		
Start Date	1st of September 2023	Duration	36 months
Project Coordinator	NTUA		
Deliverable	D2.4 - High-level requirements for the ENPOWER technological, social and business framework		
Work Package	WP2 - Connect, Benefit & Incentivise: 'Citizen engagement, interactive mechanisms, and multilevel knowledge creation in data-driven energy-secure communities'		
Delivery Month (DoA)	May 2024	Version	1.1
First Delivery Date	May 31, 2024		
Second Delivery Date	January 7, 2025		
Nature	Report	Dissemination Level	PU
Lead Beneficiary	DST		
Authors	Fabrizio De Felice (DST), Christine Gritsch (BLUEPRINT), Elena Boskov-Kovacs (BLUEPRINT)		
Quality Reviewer(s)	Tiago Soares (INESC TEC), Jose Villar (INESC TEC), Nektarios Matsagkos (NTUA), Eleni Kanellou (NTUA)		

Copyright Message

Preface

ENPOWER designs, develops, and demonstrates SSH-driven methodologies, interactive and closed-loop tools, and data-driven services for energy-activated citizens and energy-secure cross-sector communities towards a citizen-centric energy system. By combining leading-edge ICTs with social/behavioural dimensions and with sharing economy and value stacking business models the project aims to deploy: 1) a Social Science Framework for energy citizens activation and innovative multidimensional incentives for citizens' participation in energy markets; 2) AI-based consumers clustering and segmentation algorithms; 3) interactive tools and facilitation services for energy community planning; 4) Energy Data Space adaptation to support community-level data-driven activation and interoperable automated privacy and sovereignty-preserving Demand Response (DR); 5) (Peer-to-Peer) P2P DLT/Blockchain digital marketplace for tokenized energy and non-energy assets reciprocal compensation; 6) data-driven services and apps for energy efficiency and activation performance management; 7) ICT services and Digital Twins for community-level energy optimisation and aggregated flexibility management to trade off local self-consumption against grid service provisioning, while boosting a beyond-energy community social welfare; 8) Edge monitoring hubs for automated DR; 9) Business Sandbox for novel sharing economy and social innovation-based business models; 10) methodologies for evaluating different energy community setups, upscaling and replication. ENPOWER framework will be validated along 4 Front Runners energy communities' pilots and further replicated in 2 Early Adopters, covering different levels of maturity of communities, to demonstrate increased RES local self-consumption and consumers participation to the energy markets, while nurturing increased local security of supply. ENPOWER Leadership Programme and blueprints will support EU-wide replication and advice regulatory bodies on communities-friendly enabling frameworks.

Who we are.

No	Participant Name	Short Name	Country	Role
1	National Technical University of Athens	NTUA	GR	Coordinator
2	Design Strategy Technology S.r.l	DST	IT	Technology providers
3	INESC TEC - Institute for Systems and Computer Engineering, Technology and Science	INESC TEC	PT	
4	Fundación CARTIF (CARTIF Technology Center)	CARTIF	ES	
5	COMSENSUS D.O.O.	COMS	SL	
6	European Dynamics Luxembourg SA	ED	LU	
7	Audencia Business School	AUDENCIA	FR	Business modelling
8	Regulatory Assistance Project	RAP	BE	Regulatory assistance
9	ICLEI Europasekretariat GmbH	ICLEI	DE	Policy & capacity
10	University of Basel*(associated partner)*	UNIBAS	CH	Social framework
11	Blueprint Energy Solutions GMBH	BLUEPRINT	AT	Pilot 1 - Austria (Front runners)
12	OurPower Energiegenossenschaft SCE	OurPower	AT	
13	Cooperativa de Desenvolvimento Sustentável, CRL	COOPERNICO	PT	Pilot 2 - Portugal (Front runners)
14	WATT-IS SA	WATT-IS	PT	
15	Cooperativa Eléctrica do Vale D'Este CRL	CEVE	PT	
16	EnC of Chalki‘Chalkion’	ChalkiON	GR	Pilot 3 - Greece (Front runners)
17	Hellenic Association for Energy Economics	HAEE	GR	
18	Green Energy Aggregator Services SA	GEARS	GR	
19	Parity Platform P.C.	PARITY	GR	
20	Electric Power Research Institute Europe DAC	EEU	IE	Pilot 4 - Ireland (Front runners)
21	University College Cork (MaREI Centre for Energy, Climate and Marine, Environmental Research Institute)	UCC	IE	
22	DC Six Technologies Limited	DCSix	IE	
23	MOL TEIC - Dingle Hub	DINGLE HUB	IE	
24	ESB Innovation ROI Limited	ESB	IE	
25	Békéscsaba Energia ESCO Kft.	BCS	HU	Pilot 5 - Hungary (Early adopters)
26	Enasco Cleantech Alliance LLC.	ENASCO	HU	
27	Montajes Eléctricos Cuerva SL	CUERVA	ES	Pilot 6 - Spain (Early adopters)
28	VERGY COMMUNITY S.L. *(affiliated partner)*	VER	ES	

Executive Summary

This document outlines the work completed in deliverable “D2.4 – High-level requirements for the ENPOWER framework” as part of the ENPOWER project. This work was conducted under task T2.6 – “End user / business requirements and functional specifications” within WP2, focuses on defining high-level requirements through stakeholder engagement, interactive mechanisms, and multilevel knowledge creation in data-driven energy-secure communities. The primary objective of this report is to define and describe the high-level requirements for the ENPOWER framework, which will guide the development and implementation of project activities across various work packages (WPs).

The document provides an analysis of the pilots involved in the project, highlighting the regulatory frameworks, market conditions, and technological enablers. It details the methodology used for identifying and defining the high-level requirements, including stakeholder engagement and consultation processes. The requirements were validated through workshops with pilot site leaders and key technical experts to ensure their relevance and applicability.

The definition of the high-level requirements was based on a structured methodology. The process involved mapping technological enablers and identifying the necessary actions and interactions within the ENPOWER solution framework. Key high-level requirements were identified, each addressing specific aspects of the ENPOWER framework, including scope, objectives and involved stakeholders.

This document also maps the high-level requirements to the respective demonstration sites and outlining the expected outcomes. This mapping is crucial for planning the activities at each ENPOWER pilot site, ensuring that the selected services and requirements align with the overall project objectives.

Additionally, this document provides a proposed overview architecture that will be refined in the next deliverable D2.5 and further developed with the progress of the various technical tasks. This analysis lays the foundations for subsequent technical developments in WP3, WP4, WP5 and WP6.

In conclusion, this Report highlights the role of High-Lavel Requirements in Shaping the ENPOWER Project's Future Technical Developments and Pilot Implementations.

Table of Contents

1 INTRODUCTION 10
1.1 SCOPE AND OBJECTIVES OF THE ENPOWER PROJECT 10
1.2 ABOUT THIS DOCUMENT 11
1.3 STRUCTURE OF THE DELIVERABLE 12
2 END USER / BUSINESS REQUIREMENTS 13
2.1 REQUIREMENTS ANALYSIS OVERVIEW 13
2.2 METHODS FOR REQUIREMENT IDENTIFICATION 14
2.3 USER REQUIREMENTS 16
2.3.1 Introduction 16
2.3.2 ENPOWER user requirements specification 17
2.4 ENPOWER BUSINESS REQUIREMENTS SPECIFICATION 23
2.4.1 Austrian Pilot: P2P renewable energy community real time marketplace for energy and flexibility demand versus supply near time information sharing and matching 24
2.4.2 Portuguese Pilot: Combination of Community ESCO, Local Energy Markets (LEM), and E-mobility Cooperative BMs. 25
2.4.3 Greek Pilot: Integration of Community Aggregation and E-mobility Cooperative BMs. 27
2.4.4 Spanish Pilot: Combination of Community ESCO with Mobility Services and E-mobility Cooperative BMs. 28
2.4.5 Hungarian Pilot: Municipality-driven P2P market for a new local community 29
2.4.6 Irish Pilot: Cross-sector social value community-centred services for enhancing grid flexibility and paving the way for increased share of self-sufficiency 31
2.5 MAPPING BUSINESS REQUIREMENTS/USE CASES 32
3 FUNCTIONAL SPECIFICATIONS 34
3.1 FUNCTIONAL SPECIFICATIONS OVERVIEW 34
3.2 ANALYSIS OF ENPOWER FRAMEWORK 35
3.3 REVIEW OF PREVIOUS PROJECTS 36
3.3.1 BD4NRG 36
3.3.2 PlatONE 38
3.3.3 OneNet 39
3.3.4 BRIGHT 42
3.3.5 eDREAM 43
3.4 ENPOWER FUNCTIONAL SPECIFICATIONS 45
3.4.1 High Level Functional Specifications List 46
3.4.2 ENPOWER Architecture overview 77
3.5 ENPOWER BUSINESS SPECIFICATIONS 80
4 CONCLUSION 82
5 REFERENCES 84

Figures

Figure 1: Methodology scheme 15
Figure 2: BD4NRG Reference Architecture [9]. 37
Figure 3: PlatONE Framework Applied to the Italian Demo [10]. 38
Figure 4: The OneNet Reference architecture [11]. 40
Figure 5: OneNet Connector Architecture. 41
Figure 6: Conceptual BRIGHT's Architecture [12]. 42
Figure 7: eDREAM Conceptual Architecture [13]. 44
Figure 8: ENPOWER Architecture Overview. 78

Tables

Table 1: ENPOWER Technological Enablers. 13
Table 2: Technology Enablers (TEx) in ENPOWER pilots. 32

List of acronyms

ADR	Automated Demand Response
AI	Artificial Intelligence
API	Application Programming Interface
BEMS	Building Energy Management Systems
BIM	Building Information Modelling
BM	Business Model
BS	Business Scenario
CECs	Citizen EnCs
DER	Distributed Energy Resources
DR	Demand Response
DSO	Distribution System Operator
EnC	Energy Community
EV	Electric vehicles
GDPR	General Data Protection Regulation
HLUC	High-Level UC
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
IC	Indoor Comfort
ICT	Information Communication Technology
IEC	International Electrotechnical Commission
IoT	Internet of Things
KPIs	Key Performance Indicators
LEM	Local Energy Market
OEMs	Original Equipment Manufacturers
REC	Regional Energy Community
UI	User Interface
V2G	Vehicle-to-Grid
WP	Work Package

1 Introduction

1.1 Scope and Objectives of the ENPOWER project

The ENPOWER project, funded by the European Union's Horizon Europe program, aims to revolutionize how energy systems interact with citizens by fostering a consumer-centric energy system. This project seeks to harness the capabilities of cutting-edge technologies and social sciences to activate and engage European citizens as integral stakeholders in energy markets.

The information collected in this document comes from an initial analysis of the context and high-level pilots. In subsequent deliverables, this information will be implemented or slightly modified as needed.

The ENPOWER project, funded by the European Union's Horizon Europe program, is an ambitious initiative aimed at transforming the way energy systems operate in Europe. Its central goal is to create a consumer-centric energy ecosystem by activating citizens as key stakeholders in energy markets and fostering energy-secure communities. This transformation is achieved by integrating cutting-edge technologies like artificial intelligence (AI), blockchain, digital twins, and social science methodologies with innovative business models that support citizen engagement and local energy management.

The project's scope encompasses developing a comprehensive framework that integrates innovative social science methodologies, advanced Information and Communication Technology (ICT), and smart energy management strategies. By doing so, ENPOWER aims to create sustainable, secure, and highly efficient energy communities across Europe.

The primary objectives of the ENPOWER project are to:

- **Enhance Citizen Engagement:** Utilise a social science framework to promote active participation of citizens in energy markets. This involves the development of innovative incentives that encourage consumer involvement in energy trading and management.
- **Implement Advanced Technological Solutions:** Deploy AI-based consumer clustering and segmentation algorithms, interactive tools, and facilitation services to optimise community planning and energy consumption. This also includes adapting Energy Data Spaces to support community-level data-driven activation and ensuring interoperable, privacy-preserving Demand Response systems.
- **Improve Energy Efficiency and Security:** Develop ICT services and Digital Twins for community-level energy optimisation. These tools will help manage aggregated energy flexibility to balance local consumption with grid service provisioning, enhancing the local security of energy supply.
- **Facilitate Sustainable Business Models:** Establish a Business Sandbox to explore novel sharing economy and social innovation-based business models. This will aid in the evaluation and replication of energy community setups across different European regions.
- **Support Regulatory Framework Development:** Provide comprehensive blueprints and a leadership program to assist EU-wide replication of successful models and advise regulatory bodies on creating community-friendly frameworks.

1.2 About this document

The information collected in this document comes from an initial analysis of the context and pilots, and from HLUC described in D2.1. In subsequent deliverables, this information will be implemented or slightly modified as needed.

The project's comprehensive framework supports the development of decentralized energy communities that encourage sustainable, secure, and efficient energy use. By engaging citizens, ENPOWER promotes energy democracy, where consumers not only manage their own energy consumption but actively participate in energy production and trading. This approach seeks to boost renewable energy use, enhance local security of supply, and create economic opportunities within communities through value-sharing models.

This deliverable, **D2.4: High-level Requirements for the ENPOWER Technological, Social, and Business Framework**, outlines the project's high-level requirements, focusing on the integration of technological enablers and business models necessary to support these consumer-centric energy systems. It is part of Work Package 2 (WP2), which focuses on citizen engagement, interactive mechanisms, and multi-level knowledge creation within data-driven energy communities.

The deliverable provides a detailed analysis of the end-user and business requirements, functional specifications, and methodologies used to develop the ENPOWER framework. It also includes insights from pilot projects across various European countries, demonstrating how the framework can be adapted to different community needs and regulatory environments. Through its collaborative and inclusive approach, ENPOWER aims to create scalable and replicable models that can be adopted across Europe, furthering the EU's goals for sustainable energy transitions.

The technical core of the ENPOWER framework, described inside the deliverable leverages a variety of state-of-the-art technologies aimed at optimizing energy management, increasing efficiency, and enhancing consumer participation. These technical specifications are designed to empower citizens by providing real-time data on energy usage, enabling autonomous energy management, and supporting the creation of a dynamic, decentralized energy system. By deploying these technologies, ENPOWER aims to make energy consumption more efficient and transparent, while fostering increased engagement from energy users.

In parallel, the present deliverable analyses and describes the business framework of ENPOWER focusing on developing sustainable, citizen-centric energy communities through innovative business models that capitalize on the value of shared energy resources and community participation. These business specifications have been designed to create self-sustaining energy communities that are resilient, economically viable, and socially inclusive. By combining innovative business models with advanced technology, ENPOWER aims to democratize the energy system, ensuring that citizens are active participants in both energy production and consumption.

The technical and business specifications of the deliverable contribute synergistically to promote a consumer-centric, decentralized energy system across Europe. Through cutting-edge technologies and forward-thinking business models, ENPOWER empowers citizens to take control of their energy futures, enhancing both individual and community-level resilience. By fostering innovation and collaboration, the project contributes to the European Union's goals of sustainability, security, and competitiveness in the energy sector.

1.3 Structure of the deliverable

This document is organised to comprehensively present the findings, methodologies, and insights of the ENPOWER project. Each chapter is designed to address specific aspects of the project, ensuring a logical flow and easy navigation for readers. Below is an overview of each chapter included in this deliverable:

Chapter 2: End User / Business Requirements

This chapter delves into the analysis of end-user and business requisites that have significantly shaped the trajectory of the ENPOWER project. It discusses in detail the methods employed for gathering these requirements, the identification of pertinent use cases, and outlines the specific user and business demands that are crucial for guiding the project's strategic implementation.

Chapter 3: Functional Specifications

Focusing on the developed functional specifications within the ENPOWER framework, this chapter offers an extensive examination of the technological framework of the project. It emphasises the alignment of these specifications with the needs of the energy consumers and pilots involved, showcasing how they cater to the operational and efficiency demands of the project.

2 End User / Business Requirements

2.1 Requirements Analysis Overview

The requirements analysis development focused on the engagement with the key stakeholders, including Technological Enabler (TE) leaders and pilot leaders to understand their needs. It was based on different iterations and on the feedback received from stakeholders to ensure that the ENPOWER project is designed and implemented to effectively address their needs and to deliver real value. These are the main steps followed:

1. The organization of a workshop with each TE leader to analyse the existing technological solutions.
2. The organization and development of the co-creation workshops for each pilot to establish a direct dialogue with the stakeholders and to extract the user requirements.
3. The analysis of the user requirements gathered and the definition of the new features to develop for the ENPOWER project.

Table 1: ENPOWER Technological Enablers.

TE #	TE Description	Partner
TE-1	Interactive decision support tool for EnC planning	CARTIF, INESC TEC
TE-2	SITEC-Sizing tool for EnCs	INESC TEC
TE-3	CRP social engagement management platform	DCsix, EPRI
TE-4	Energy Data Space compliant tools for sovereign data management, sematic interoperability and exploitation	ED, DST
TE-5	DLT/Blockchain/smart contracts multi-purpose marketplace for increased Trust & Sovereignty and for P2P tokenised assets sharing and compensation	DST
TE-6	Digital Twins for consumer activation	INESC TEC, DST
TE-7	Consumers clustering and segmentation tools	NTUA, UNIBAS
TE-8	FATEC - Flexibility Assessment tool for EnCs	INESC TEC
TE-9	Self-consumption optimisation tool	NTUA, GEARS
TE-10	Closed-loop optimal load control and intelligent monitoring of electric appliances for residential users	NTUA, COMS
TE-11	V2G-based flexibility management platform for providing incentives to communities of EV drivers	PARITY
TE-12	OSTEC-Optimised Scheduling Tool for EnCs	INESC TEC
TE-13	AI-Powered Virtual Energy Manager (WIS4Households)	WATT-IS

TE-14	Nudging Apps for near real time closed loop consumers activation	OurPower, BLUEPRINT
TE-15	Blockchain-based hybrid coalition-based flexibility aggregation tool	DST, COMS
TE-16	P2P digital tools and platforms for consumer activation and social engagement	OurPower, BLUEPRINT
TE-17	P2P energy markets designs and algorithms	INESC TEC
TE-18	Privacy preserving tools for automated interoperable DR	EPRI, DCSix, MaREI, COMS

The main goal of this section is to perform an analysis of the pilots' and consumers' needs that will be formalised as business and technical requirements, derived from use cases [1]. Starting from the High-Level Use Case (HLUC) defined in D2.1, the main outcome of this analysis is formalised in Use Case (UC). In D2.1, 8 HLUCs were identified, divided into 5 domains:

- Digitalisation of EnCs
- Forecasting and modelling of EnCs
- Smart Controls for EnC optimisation
- EnC market operation
- User-centred Interaction in support of EnCs.

Note that each UC represents specific functionalities of the ENPOWER system and may not be applicable to all demo sites.

2.2 Methods for Requirement Identification

Task 2.6 methodology is based on the direct involvement of the end-users in a set of participatory processes to extract the requirements that these end users would have to play a role in the aggregated Demand Response (DR) markets. Two main subgroups of end users have been identified that can also be applied for all types of energy community designs/topologies: consumers/prosumers driven cooperatives or municipality/utility driven cooperatives taking up the role of aggregators of demand flexibility for domestic users demand management [2] [3].

- End user drive energy communities (sometimes in countries like Austria and the CEE region structured largely as "Cooperatives"), as potential demand flexibility aggregators: any energy cooperative in Europe may become potential end users of the ENPOWER services and applications and may be in the position to provide their inputs and requirements to this purpose. To narrow down the possible sample of cooperatives, and collect differential issues, three groups of cooperatives are designed with different approach methodologies.
- Municipality or utility-driven cooperatives have different incentives: focusing on improving grid and supply conditions for the residents.

The methodology followed in Task T2.6 is a top-down approach, depicted in the following chart. The starting point is the main default business case of the project concept, which involves cooperatives as domestic demand flexibility aggregators. A task group is formed to define the most interesting possible Business Scenarios (BS) for cooperatives, getting feedback from the ENPOWER consortium cooperatives. This preliminary list of BSs has been derived into real business models as part of task T2.5 and deliverable D2.3. Work performed in the Business Sandbox is a prerequisite for clearly settling the scope of the project and the functionalities to be developed along the project. The scope of the project delimits the type of information that is needed from the initial list of UCs or high-level operational functionalities.

Once the high-level basic UCs both for cooperatives and for prosumers have been defined, the type of information from end users that is needed to develop the expected functionality according to the end users' requirements can be requested. Two lists of basic information needs, one for domestic end users and another for aggregators, are compiled with the collaboration of the full ENPOWER partnership. The information needs from the project partners are classified by topic, filtered and associated with specific use cases.

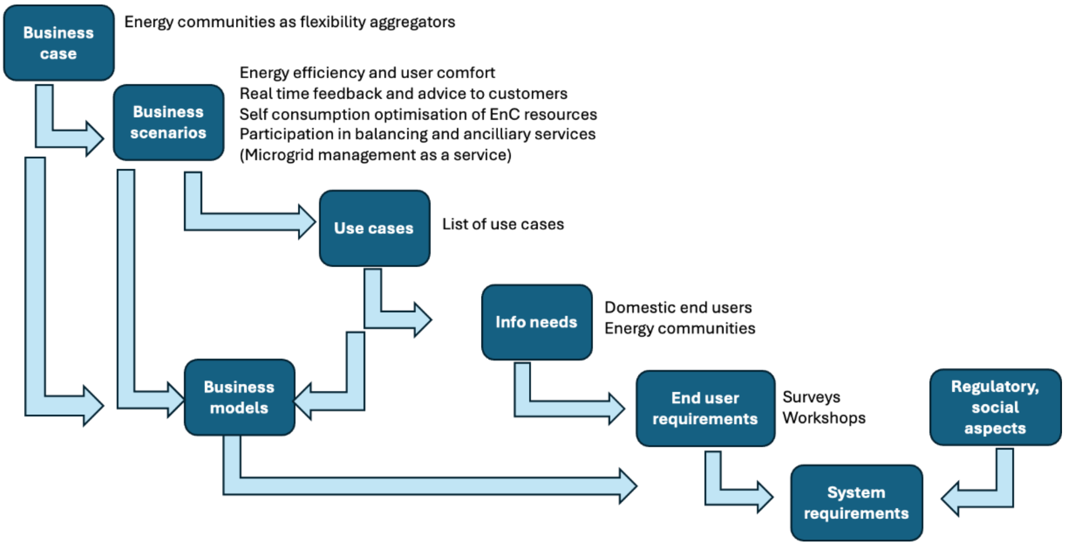

Figure 1: Methodology scheme.

The requirements of the end users have been outlined by the project partners to help clearly define their task outcomes. Initially, cooperatives acting as potential demand aggregators – small rural cooperatives with installed renewable production in Austria, or utility (DSO) driven communities as the one in Spain, specify BSs. Following this, UCs for ENPOWER solutions are identified. From these UCs, partners compile a list of necessary information to ensure their efforts are aligned with end user requirements, ensuring that the final solutions meet these needs.

The information to be collected from domestic end users in the project is categorized into several groups:

- Profile Information: This includes end user profile data, household composition, and building characteristics within the energy community. This data aids in segmentation and statistical analysis.
- EnC Equipment and Installations: Information about energy-consuming devices at home, particularly focusing on HVAC, renewables production and consumption, as well as the smartness of associated devices.
- Contracting and Consumption: Details about the type of supply contract and the economic impact of energy consumption on the household budget.
- Attitude Towards Participation: End user attitudes towards participation in DR markets (as described in D2.2 in terms of trust, willingness to join an energy community etc) and the use of smart technology at home.

- Familiarity with Concepts: Awareness and understanding of smart grids, self-consumption, smart appliances, etc.
- Incentives and Barriers: Factors such as regulatory ones that motivate or hinder participation in DR markets.

To gather this information from end users, several participatory processes were employed. The choice of process depends on the type and specificity of the information, its complexity, the need for contextualization, and the importance of detail and accuracy in the responses. Topics or questions are then assigned to the most appropriate participatory process accordingly.

Two main methodologies have been used:

- Surveys, meant for a large sample of respondents but giving little response resolution or low second level details. The transfer of information is unidirectional and there is no possibility to refine the answers. This work has been conducted as part of T2.2.
- Focus groups and workshops, meant for a low number of participants, but enabling direct questions, iterations, context awareness and doubt resolution in a bilateral exchange of information, as part of T2.3.

The output of these participatory processes will be complemented by the requirements of the regulatory framework, both at the EU level and at the national level, within T2.1. This task also addresses the ethical, cultural and socioeconomic perspective by analysing barriers and incentives to the BSs performed as part of T2.4 and T2.5, from the end users' point of view.

2.3 User requirements

2.3.1 Introduction

Empirical data as outcome from T2.2 and T2.3 as well as conducted workshops, were collected using both qualitative and quantitative methods across pilot sites that are part of the ENPOWER project, as well as from the general public in six countries: Austria, Ireland, Portugal, Hungary, Spain, and Greece.

Results from the survey and analysis conducted in Tasks 2.2 and 2.3 revealed that most respondents are interested in becoming energy citizens and are open to joining an EnC. The perceived benefits of EnC membership include reduced energy costs, a decreased environmental impact, and increased energy autonomy. To engage people in EnCs, the survey indicated a preference, rather from daily interaction, one on a quarterly or monthly engagement in energy community initiatives, with a strong interest in financial investments in renewable energy sources with returns. Notably, respondents are open to automated electricity consumption provided it can be overridden, - opted out, suggesting that designing EnCs with this opt in and out flexibility as a default is crucial. The primary barrier to EnC membership was a lack of knowledge, not only about what EnCs are and their benefits but also because many respondents were unaware of any EnCs in their area. This underscores the need for more extensive media campaigns to promote EnCs or the creation of more EnCs.

Qualitative research supports these findings, showing that most EnCs are well-subscribed and have significant growth potential due to increasing demand from engaged citizens. In Hungary, where energy prices are heavily subsidized for citizens, similar findings were observed, but municipalities and SMEs were the primary target members for EnCs rather than individual citizens.

Regarding the use of apps to enhance citizen engagement, focus groups suggested that the app design should be straightforward, incorporating a variety of features. Ideally, the app should display real-time data on both individual and community energy usage and production. Additionally, energy consumption processes could be automatically managed to optimise the entire community's energy use. It is also important to define specific target audiences and consider gender inclusion, as the energy domain tends to not be gender neutral, but rather favouring male population.

Clustering analysis using Machine Learning (ML) on residential energy consumption loads highlights the importance of tailored approaches and methodologies for creating data-driven, energy-secure communities and empowering citizens to make informed energy choices.

Potential partnerships between municipalities and EnCs can take several forms, such as using public spaces and rooftops for renewable installations, raising awareness, visibly endorsing EnCs, sharing energy, municipal staff and resources, and bringing together different stakeholders.

In summary, tailored engagement efforts within communities and EnCs can foster active participation and collaboration, empowering individuals to contribute to sustainable energy practices and become energy citizens. Customized strategies are essential for developing a consumer-centred energy model, promoting engaged citizens, and enhancing data-driven, secure EnCs. These approaches facilitate informed consumption decisions and significantly improve energy resilience and equity within communities.

2.3.2 ENPOWER user requirements specification

This section presents the findings from interviews conducted with coordinators and management teams of EnCs across six pilot sites. The research focused on identifying strategies to enhance user engagement within these communities. The analysis revealed a diverse range of motivational factors and engagement approaches tailored to each community's unique context.

2.3.2.1 Motivational Factors

Key motivational factors identified for participation in EnCs include:

- Financial Incentives: Participants are primarily driven by economic benefits. These include reduced energy costs, financial returns from community projects, and incentives for adopting renewable energy technologies. The prospect of tangible economic benefits increases the likelihood of participation in EnCs.
- Energy Citizenship: Engagement is significantly motivated by the desire to actively participate in the energy system. EnCs provide a platform for citizens to transition from passive consumers to active participants, fostering a sense of agency and collective decision-making. This transformation empowers individuals to contribute to and influence energy-related decisions within their community.
- Environmental Protection: Many participants are motivated by the opportunity to contribute to the clean energy transition and reduce the environmental impact of their energy use. By using renewable energy, participants can help improve local air quality, reduce pollution, and contribute to the mitigation of global climate change.

2.3.2.2 Engagement Strategies

To engage and activate people in EnCs, various strategies were pursued as part of work conducted in Task 2.2 and 2.3 and will continue to be conducted until the end of WP2 activities, tailored to the specific context of each pilot site. These strategies included:

- Educational Workshops: Educational workshops are crucial tools for engagement. They serve as platforms to disseminate information, raise awareness, and empower community members with knowledge about the energy transition, renewable energy technologies, and the benefits of active participation. Workshops help demystify technical concepts and provide practical insights into energy management.

- Tailored Communication: Communication strategies were customized to address the specific information needs, social environments, economic situations, and preferences of different community members. The use of social media platforms emerged as the most utilized tool for communication. Depending on the community, it is planned for other media channels like radio and newspapers to possibly be employed in the future, depending on engagement tracking. Social media was particularly effective for community building, allowing members to express opinions and participate in discussions about energy-related initiatives.
- Community Building Activities: Creating a sense of identity and belonging within the community was vital. Organizing community events, celebrations, and collaborative projects helped foster emotional investment in the EnC's collective vision. These activities provided opportunities for community members to come together, share experiences, and build a stronger sense of community.
- Stakeholder Engagement: Effective engagement with different stakeholders and policymakers was essential for the success of community energy projects. This involved coordinated efforts across various actors and institutions, including governments, public and private organizations, and the communities themselves. Building relationships with stakeholders helped secure support, resources, and legitimacy for the EnCs.

2.3.2.3 Barriers to Engagement

Despite the successful implementation of various strategies, several barriers to engagement were identified in D2.2:

- Legislative Hurdles: National and local legislation often posed significant barriers to engagement. These legal challenges could delay or complicate the initiation and continuation of community energy projects. Navigating the regulatory landscape was a common issue that required attention and strategic planning.
- Knowledge Gaps: A lack of awareness about EnCs and the broader energy system was a prevalent challenge. Potential participants often lacked the necessary information to understand the benefits and functioning of EnCs. Addressing these knowledge gaps through targeted educational efforts was crucial.
- Social Reluctance: Social reluctance to change and distrust in the efficiency of new energy systems were significant barriers. Some community members were hesitant to adopt new practices and technologies, preferring the familiarity of existing systems. Overcoming this reluctance required building trust and demonstrating the reliability and benefits of EnCs. Overall, the results underscored the need for tailored interventions to address the unique characteristics, cultural backgrounds, and preferences of each community. Addressing knowledge gaps, fostering community identity, and enhancing stakeholder participation were recurring themes across all EnCs. The following graph summarizes the results of the engagement factors and strategies in the EnC.

Specific Engagement Activities: Deliberative Citizen Engagement Workshops on Energy Data Sharing

Deliberative citizen engagement workshops aimed to gather insights into participants' opinions, attitudes, and perspectives on energy data sharing. This collaborative and iterative process was designed to inform project partners about participant contributions and outcomes. The workshops provided a platform for citizens to engage in shaping public policies and decisions affecting their lives, ultimately contributing to a more participatory and democratic society.

During the workshops conducted as part of Task 2.3, participants were asked four key questions via Slido:

1. What comes to mind when you think about energy data sharing?
2. What is the value of data sharing?
3. What concerns do you have about data sharing?
4. What future opportunities could there be for data sharing?

The main themes identified from the responses were:

- Engagement: Effective engagement is crucial for addressing the topic of energy data sharing. Participants highlighted the need for active community involvement in discussions and decisions related to data sharing.
- Financial Benefits: Data sharing can lead to cost savings for the community and enhance its negotiating power with energy providers. Participants saw potential economic advantages in sharing energy data.
- Non-Financial Benefits: Beyond financial gains, data sharing was seen as a pathway to a more sustainable and greener future. Participants recognized the potential for increased community power in negotiating with grid providers and improving overall energy management.
- Concerns and Uncertainty: Participants expressed concerns about data security, privacy, and the use of data. Questions about how data would be stored, processed, and used were common, reflecting a need for transparency and trust.
- Privacy Concerns: Ensuring compliance with the General Data Protection Regulation (GDPR) and addressing privacy issues were critical concerns. Participants wanted assurances that their data would be handled securely and responsibly.
- Education: Educating communities and individuals about the benefits of data sharing was seen as essential. Demonstrating tangible benefits, such as a comparison of energy consumption before and after participation, could help build support.
- Sharing Information: Participants discussed the logistics and impacts of data sharing, considering how data could be shared effectively and its potential positive effects on the community.

The deliberative citizen engagement workshops provided valuable insights into the diversity of perceptions regarding energy data sharing. Addressing concerns about data security and privacy will be crucial for engaging citizens in data-driven EnCs.

Specific Engagement Activities: App Features to Engage Current and Future EnC Members

The OurPower energy cooperative offers a platform for small-scale energy producers to trade electricity generated from renewable sources with customers. OurPower is co-developing an app, Serve-U, aimed at optimising community energy efficiency by aligning consumption with available resources. The app prototype uses predictive data based on weather forecasts for production and historical consumption data for consumption patterns. This integration helps predict optimal consumption periods and provides users with actionable recommendations.

OurPower's continuous commitment to fostering EnCs led to the investigation of how an app can support engagement and energy management. Focus group discussions provided valuable inputs from prototype testers and individuals unfamiliar with the app.

Key findings from the focus groups included:

1. Simplified App Layout: Participants emphasized the importance of a simple app layout that focuses on essential items. Symbolic language, such as using a "traffic light" system to indicate energy availability, was suggested to enhance user-friendliness.
2. Engagement Features: The app should engage users with various features, particularly financial and social stimuli. Financial features could display energy cost savings achieved through efficient practices. Social incentive features should facilitate interaction and community building, allowing users to exchange tips and support each other.
3. Real-Time Data Display: Participants expressed a desire for real-time data on their energy usage and the community's consumption and production. This feature would enable users to align their actions with accurate information and understand the financial and energy-saving impacts of their behaviour.

Target audience considerations also emerged, highlighting the need for gender-inclusive design to engage more female users. While no specific ideas were provided, the focus groups recognized the importance of reaching a diverse user base.

In conclusion, the Serve-U and DOMX apps hold significant potential for enhancing citizen engagement and energy management within EnCs. Simplified design, real-time data, and interactive features are critical to its success. Tailored approaches, as discussed, are essential for effective engagement, ensuring the apps meet the varied needs of their users.

Understanding Stakeholder Preferences in Energy Communities

Understanding the preferences of stakeholders in EnCs is crucial for their success. This section examines various approaches to stakeholder engagement, focusing specifically on the roles and relationships of municipalities and companies within EnCs. By analysing centralized EnC initiatives led by these entities, we explore their motivations, barriers, and engagement strategies based on interviews conducted in Hungary and a review of relevant literature.

Municipalities' Role and Motivations

Municipalities play a pivotal role in driving the green transition within local communities. Local authorities often spearhead development efforts, handling critical issues that affect the community. Despite bureaucratic challenges, municipalities are significant forces in establishing EnCs. Interviews and literature reviews reveal several key motivational factors for municipalities:

- Economic Incentives: Economic benefits are a primary motivator. Selected studies [4] [5] highlight that cost reductions from energy savings and potential revenues from selling excess energy are substantial incentives. These financial gains can lead to indirect economic benefits, such as job creation and increased local spending, stimulating the local economy.

- Environmental Responsibility: Municipalities are major consumers and producers of greenhouse gases. Their commitment to reducing emissions makes them crucial players in the green transition. Supporting EnCs can lead to more environmentally conscious behaviour and enhance the municipality's political legitimacy.

- Energy Security of supply: Ensuring stable energy supplies is a significant driver. EnCs can mitigate energy security issues by reducing dependence on external energy sources.
- Social Cohesion: Establishing EnCs fosters closer relationships among residents, enhancing local social capital and cooperation in other community areas.

Companies' Role and Motivations

Companies, especially small and medium-sized enterprises (SMEs) and industrial parks, also play a vital role in supporting EnCs. Their motivations include:

- Cost Reduction: Like municipalities, companies are driven by the potential for significant cost savings. Larger energy consumers, such as industrial parks, see clearer financial benefits from joining EnCs.
- Market Advantage: The green energy transition offers companies a competitive edge, enabling price competitiveness, market expansion, and compliance with EU regulations.
- Local Engagement: Companies with local ties, where employees are residents, are more motivated to participate in EnCs. This involvement supports the local economy and enhances the company's image.
- Resource Optimisation: EnCs facilitate resource sharing among companies, leading to optimised infrastructure use and technological advancements.
- Professional Benefits: Participation in EnCs provides technological and professional advantages, fostering innovation and development.

Barriers to Engagement

Despite the benefits, several barriers hinder the engagement of municipalities and companies in EnCs:

- Economic Constraints: Municipalities often face financial limitations due to high upfront costs and long-term investment returns.
- Administrative Challenges: Project development and financing issues, coupled with bureaucratic hurdles, pose significant obstacles.
- Social Reluctance: Lack of community support and trust in renewable energy initiatives can be problematic, particularly in regions where EnCs are not yet common.
- Corporate Hesitation: Companies may fear losing autonomy or be uncertain about the profitability and technical challenges of EnCs. Regulatory compliance and eligibility issues also deter engagement.
- Legal and Regulatory Environment: In Hungary in particular, the regulatory environment poses significant challenges for establishing EnCs. Interviews identified three main regulatory barriers:
    - Electricity Regulations: Competing with state-subsidized universal service prices is challenging for EnCs.
    - Taxation Issues: The tax implications of shared energy require thorough exploration.

  - Corporate Law: Ownership and membership issues complicate the development of appropriate partnership structures.

European Perspective and Municipal Engagement - Preferred Partnership Models

Municipalities and companies generally prefer partnership models that emphasize democratic governance, with each EnC member having one vote. Professional management or citizens' councils are also favoured to promote and manage the energy transition. EnCs are often set up as non-profit organizations or cooperatives, aligning with EU legislation that encourages inclusive and citizen-led initiatives.

EU legislation supports public authorities' engagement with Renewable EnCs (RECs) and Citizen EnCs (CECs). The EU Solar Energy Strategy calls for one renewables-based EnC per municipality with over 10,000 residents by 2025. Municipalities view EnCs as tools to increase local socio-economic value and reduce energy costs [6]. Promoting citizen participation in energy systems is often seen as means to achieve broader local climate and energy planning goals [7] [8].

Examples of Municipal and EnC Partnerships

Various partnership models between municipalities and EnCs include:

- Infrastructure Provision: Municipalities can provide public spaces for EnC assets, reducing investment costs.
- Awareness and Endorsement: Municipalities can raise awareness and endorse EnC activities to attract more participants.
- Resource Sharing: Municipalities can share staff and resources or join EnC boards to provide leadership.
- Public Tenders: EnCs can participate in public tenders with provisions for citizen participation.
- Financial Support: Municipalities can set targets for EnC promotion and provide dedicated funds.
- Stakeholder Collaboration: Municipalities can facilitate co-creation and innovation through stakeholder engagement.
- Economic Benefits: Municipalities can profit from stable tax revenues and access to local renewable energy sources through Power Purchasing Agreements (PPAs).

In conclusion, while the potential for municipalities and companies to support and benefit from EnCs is clear, overcoming economic, administrative, and social barriers is crucial. Tailored partnership models and regulatory adjustments are necessary to foster effective engagement and realize the full benefits of EnCs.

Business requirements

Introduction and methodology

In crafting business requirements for pilot sites of EnCs, it's crucial to understand the importance of different business models (BMs) that shape how these communities operate. BMs, developed as part of D2.3, lay the groundwork for how resources are used, how things work, and how different parts of the community connect. So, it is essential to grasp the details of these models to outline the specific needs for successful pilot sites. These requirements guide how things are done and set out the goals and methods needed to make sustainable energy transitions happen in communities. Understanding these models helps coordinate the involvement of different people, technologies, and energy sources in ENPOWER.

Overview of Innovative Consumer-Centric BMs

1. Diversity of Actors: The EC BMs incorporate various stakeholders at local, regional, and national levels, including prosumers, consumers, communities, networks, and market operators. Each stakeholder plays a crucial role in driving the success of the EC, ensuring inclusivity and transparency.
2. Direct Relationships: Emphasis on fostering direct relationships between stakeholders to facilitate dynamic energy sharing and data exchanges. These relationships promote trust and collaboration, essential for the smooth functioning of ECs.
3. Increased Citizen Empowerment: Leveraging innovative and smart technologies to empower citizens with increased decision-making powers and responsibilities. By involving citizens in the energy production and management processes, ECs promote a sense of ownership and responsibility within communities.
4. Customized Archetypes: Development of fully customized archetypes within a consumer-centric perspective to meet individual energy citizens' needs. These archetypes ensure that ECs are tailored to the specific requirements and preferences of the communities they serve, enhancing efficiency and effectiveness.

Key Characteristics of Innovative BMs

1. Decentralization: Shift from centralized to decentralized and local energy production, promoting energy autonomy and resilience within communities.
2. Digitalization: Integration of sophisticated ICT, net-metering infrastructures, and software-based trading platforms to enable real-time monitoring and management of energy resources.
3. Flexibility: Use flexibility assets, such as V2G technologies and smart meters, for load management and optimisation, ensuring efficient resource allocation.
4. Community Engagement: Promotion of community engagement through shared decision-making processes and stakeholder empowerment, fostering a sense of ownership and responsibility.

These will be further elaborated in the technical requirements Section 3.

2.4 ENPOWER business requirements specification

Given the unique characteristics of the six ENPOWER EnCs, we tailored a specific approach for each pilot case, considering their different countries, demographic characteristics, regulatory frameworks, stakeholders, and applied technologies. The business model innovation process is initiated by various actors who may be loosely or strictly coordinated, rather than by a single main entity.

First, we applied the Business Model Canvas (BMC) framework to each pilot to capture key activities, modes of operation, and main actors, thereby understanding the EnCs' rationale and identifying strengths and barriers to development. We then matched our cases with one or more of the identified archetypes and analysed the energy, money, and data flows. Finally, we designed the flows resulting from the use of technical enablers in each pilot community, recording the power these enablers give to energy citizens during decision-making, their range of participation, and the level of community interaction with involved actors.

2.4.1 Austrian Pilot: P2P renewable energy community real time marketplace for energy and flexibility demand versus supply near time information sharing and matching

The EnC (Energiegemeinschaft-Regional Energy Community Dreißgen-Spörbichl-REC DS) in the case of the Austrian Pilot, is a sub-Community of OurPower Association operating in the Mühlvierte region located in Upper Austria. The key goals of the Austrian Pilot are the promotion of renewable local energy generation, the guarantee of stable prices for energy producers and energy consumers, which entails regional value creation and the integration of the EnC and its participants as aggregated energy producers/consumers in the P2P marketplace. OurPower, as the umbrella organization will facilitate the Community's integration in the marketplace and will mediate as a stability factor for the P2P contracts, providing settlement services and undertaking initiatives to leverage citizens' power to enhance Community involvement.

- **Promotion of Renewable Local Energy Generation**
  - Develop communal infrastructure for energy generation, focusing on PV and wind turbines.
  - Encourage active participation from individuals, SMEs, and farmers as energy prosumers and consumers.
  - Utilize TE-1 to provide access to the economic, social, and environmental benefits of becoming a community member or prosumer.
- **Stable Energy Prices and Regional Value Creation**
  - Ensure stable prices for energy producers and consumers through P2P marketplace facilitation by OurPower.
  - Guarantee regional value creation by maintaining consistent energy prices within the Community.
  - Implement TE-4 to manage and connect all digital platforms securely, ensuring efficient data management.
- **Integration into P2P Marketplace**
  - Integrate the EnC and its participants as aggregated energy producers/consumers in the P2P marketplace managed by OurPower.
  - Leverage Blockchain technologies and smart contracts (TE-5 and TE-15) for secure and transparent energy trading.
  - Establish agreements with the DSO and energy retailers for system reliability and management.
- **Community Engagement and Democratic Participation**
  - Foster democratic decision-making procedures to ensure fair benefits and participation among citizens.
  - Enhance public/civic life participation and provide opportunities for citizens to express their opinions through public consultations (TE-1).
  - Strengthen Community engagement with TE-4 and TE-5, ensuring secure data sharing and management.

- **Smart Grid and Energy Management**
  - Implement TE-14 to provide recent and forecast values of generation and consumption, and offer advice on energy use.
  - Use TE-16 to give citizens full market access, enabling direct, bilateral interactions and enhancing social participation.
  - Apply customer clustering and segmentation tools (TE-7) to understand socioeconomic characteristics and bundle behaviours.
- **Utilization of Technical Enablers**
  - Use TE-6 to apply different business and social dimensions from various pilots to the Austrian pilot, considering individual, community, and aggregation levels.
  - Utilize TE-14 as a communication channel between participants and the Community, including community dialogs and online event notifications for feedback.
  - Strengthen energy democracy and optimise Community energy use, balance, and economy through TE-16.
- **Partnership and Collaboration**
  - Collaborate with key strategic partners including OurPower SCE (Community Aggregator), IT and technology providers, Energiebezirk Freistadt, and other local entities.
  - Ensure active participation from all partners in managing energy generation, digital activities, and fostering Community engagement.
  - Promote the integration of diverse partners in the P2P marketplace for energy trading and stability.

2.4.2 Portuguese Pilot: Combination of Community ESCO, Local Energy Markets (LEM), and E-mobility Cooperative BMs.

Portugal, with its diverse energy landscape and strong community ties, provides an ideal setting for the implementation of innovative EC BMs. The pilot project integrates Community ESCO, LEM, and E-mobility Cooperative BMs to create a comprehensive energy ecosystem. By leveraging dynamic energy sharing and data exchanges, the pilot aims to increase local collective self-consumption and promote renewable energy generation.

- **Partnership Formation:**
  - COOPERNICO and CEVE must establish a collaborative partnership to create and operate the Portuguese pilot Energy Community (EC).
- **Integration of BM Archetypes:**
  - The pilot EC must combine the archetypes of Community ESCO, Collective Self-Consumption, and E-mobility Cooperative BMs.
  - This integration aims to increase local collective and guided self-consumption, generate renewable energy, and foster shared responsibility for energy consumption.
- **Ownership and Operation:**

  - Members of the EC will collectively own and operate renewable generation systems such as PVs, wind turbines, and hydraulic projects.
  - Collective control over energy management within the Community ensures efficient operations.
- **ESCO Remuneration Scheme:**
  - The EC will implement an ESCO remuneration scheme based on pre-defined, guaranteed savings from Power Purchase Agreements (PPAs), production projects, and energy supplier services.
  - Additionally, the ESCO will provide consulting and technology training to members and the Community.
- **Role Assignment:**
  - CEVE will serve as the local Distribution System Operator (DSO) responsible for energy management within the Community.
  - COOPERNICO will undertake the energy aggregation role, managing surplus renewable energy from prosumers and allocating it among all energy participants.
- **Implementation of LEM BM:**
  - The pilot EC will implement the Local Energy Markets (LEM) BM archetype to maximize self-sufficiency and decrease energy trading outside the Community.
  - Key characteristics include clean, affordable decentralisation of energy production, optimisation of local energy flows, and enhanced energy efficiency.
- **Digitalization and Infrastructure:**
  - Digitalization efforts will ensure the successful operation of energy, data exchange, and financial transactions.
  - Implementation of sophisticated ICT, net-metering infrastructures, and software-based trading platforms is essential.
  - A cloud-based data infrastructure with IoT devices connected to smart meters and energy production installations will provide real-time monitoring and access to energy-related data.
- **P2P Trading Integration:**
  - LEM-related BMs will integrate P2P trading to allow Community members to negotiate directly or via intermediaries, solving local energy imbalances and finding the best matches at affordable prices.
- **E-mobility Services:**
  - The pilot Community will incorporate e-mobility services utilizing energy generated by community members (prosumers).
  - Community-owned charging stations will be made available to both members and external customers to increase revenue sources.
  - Promotion of green transportation and e-mobility solutions through shared decision-making processes will strengthen community engagement.

2.4.3 Greek Pilot: Integration of Community Aggregation and E-mobility Cooperative BMs.

Greece, characterized by its unique geographical and socio-economic factors, presents opportunities for the integration of Community Aggregation and E-mobility Cooperative BMs. The pilot project focuses on increasing local self-consumption and optimising load control through the utilization of E-mobility services. By trading excess energy for non-energy assets and social services, the pilot aims to enhance community resilience and well-being.

- **Formation of EnC:**
  - ChalkiON Enc establishes the energy community with the goal of achieving complete green energy production on the island of Chalki and reducing dependence on conventional electricity imported from Rhodes.
  - EnC members include residents of Chalki and Rhodes, the Chalki Municipality, and business owners.
- **Business Model Establishment:**
  - The established business model combines Community Aggregation and E-Mobility Cooperative archetypes to increase local self-consumption and optimise load control.
  - E-mobility services will play a significant role, especially during peak tourism seasons, with the future incorporation of Vehicle-to-Grid (V2G) technology.
- **Revenue Generation and Allocation:**
  - The combined business model aims to reduce energy bills for all customers through the production of solar PV panels, water pumping, and utilization of EV batteries for grid flexibility.
  - Revenue from trading excess energy will be used for non-energy assets such as social services and further reduced electricity bills for vulnerable populations.
- **Remuneration Scheme:**
  - The current remuneration scheme engages Community members in demand-side management strategies by selling surplus energy to the outside market and providing demand flexibility through aggregation services.
  - Introduction of V2G services will enhance this scheme, facilitating the transition of consumers to prosumers.
- **Community Aggregation Implementation:**
  - The Community Aggregation archetype will be adapted to the Greek Pilot to enhance flexibility management and increase traded volumes of locally produced energy.
  - Flexible assets such as air-conditioning, heat-pumps, and water networks will be utilized to improve self-consumption and self-sufficiency.
- **Smart Meter Installation and Mapping:**
  - Additional smart meters will be installed in residential households, tourist apartments, and businesses to analyse consumption patterns and optimise energy usage.

- Mapping will be constructed to identify optimal time frames for energy consumption, improving water desalination management and storage utilisation.

- **Implementation of E-mobility Cooperative:**
  - The E-mobility Cooperative archetype will be implemented to exploit EVs and E-Boats, introducing V2G as storage and designing smart charging schemes.
  - E-chargers will be made available to both EnC members and external customers to generate additional profit.
- **Load Schedule Operations:**
  - Load schedule operations will be conducted to optimise local resources and minimise dependency on conventional generation during off-peak high demand periods.
  - Flexibility assessment and self-consumption sizing tools will be developed to allow members to interfere with load patterns and take advantage of low demand hours.
- **Stakeholder Involvement:**
  - Stakeholders include prosumers with rooftop PV ownership, the municipality managing the PV farm, and consumers contributing financially to the PV farm.

2.4.4 Spanish Pilot: Combination of Community ESCO with Mobility Services and E-mobility Cooperative BMs.

Spain, known for its progressive approach to renewable energy and community engagement, serves as a fertile ground for the integration of Community ESCO with Mobility Services and E-mobility Cooperative BMs. The pilot project emphasises enhancing self-consumption levels and optimising scheduling through the utilization of flexibility assets within the community. By installing V2G e-chargers and leveraging Living Lab platforms, the pilot aims to empower stakeholders and drive sustainable energy transitions.

- **Stakeholder Engagement:**
  - Vergy and CUERVA, the community developers, establish close ties with Fornes Town Council, City Hall office, school, medical service, swimming pool, and the Utility Provider to ensure successful development.
  - Utility Provider assumes the role of an external company investing in the establishment of the EnC, representing the Community ESCO BM archetype.
  - Integration of V2G projects introduces an additional tier of the E-mobility Cooperative BM archetype.
- **Objective:**
  - Enhance self-consumption levels and optimise scheduling by utilising flexibility assets within the community.
  - Raise consumer awareness and foster greater engagement within the community.
- **Revenue Enhancement:**

- Community ESCO BM archetype serves as a pivotal focal point, enhancing the income stream through reduced external power supply demands and diverse Energy Efficiency (EE) strategies.
- The initiative could expand its reach by offering services to customers beyond the community confines.

- **Capacity Enhancement:**
  - Installation of additional capacity for the PV plant, reaching a total of 100kW, to bolster the community's self-consumption levels and diminish external power supply demands.
  - Addition of batteries and V2G technology as storage solutions to further increase self-consumption and offer e-mobility services.
- **V2G E-Chargers Installation:**
  - Installation of V2G e-chargers to secure benefits including generation of income stream, implementation of e-mobility services for both EnC members and external customers, including the use of V2G technology as a flexibility asset.
- **Hybrid Business Models:**
  - Integration of flexibility and mobility solutions into hybrid Business Models, offering an all-inclusive approach to sustainable energy management.
- **Leveraging Living Lab Platform:**
  - Utilization of grants for real-time data acquisition on production and consumption through the Living Lab platform.
  - Implementation of advanced tools such as the AI-Powered Virtual Manager, OSTEC-Optimised Scheduling Tool for EnCs, and SITEC-Sizing tool for EnCs to optimise energy consumption, scheduling, and resource allocation.
- **Community Empowerment:**
  - Empowerment of stakeholders by providing necessary tools and information to dynamically participate in decision-making processes and contribute to the overall sustainability goals of the EnC.

2.4.5 Hungarian Pilot: Municipality-driven P2P market for a new local community

The EnC in the case of Hungarian Pilot, has not yet been established, as they are still an early adopter, but is under development as the Bekscsaba Energia Esco Ltd. is a fully municipality-established and owned legal entity. Key goals of the Hungarian Pilot are promotion of renewable local energy generation, energy exchange between Community members creating a P2P marketplace with the help of OurPower, increase Community engagement and provide E-mobility services. Key partners of the EnC are the municipality and public buildings, businesses and SMEs, the DSO, the Bekscsaba Energia Esco Ltd., energy suppliers, technology, service and mobility providers, as well as the public transportation company.

- **Promotion of Renewable Local Energy Generation**
  - Establish partnerships with technology and service providers to promote renewable energy.
  - Implement the Self-consumption optimisation tool (TE-9) to enhance local energy generation and consumption.

- **Energy Exchange and P2P Marketplace**
  - Create a P2P marketplace with the help of OurPower for energy exchange between Community members.
  - Ensure the trading platform is supported by real-time data from the Smart Grid monitoring platform operated by ENASCO.
  - Establish Closed-loop optimal load control and intelligent monitoring of electric appliances for residential users (TE-10).
  - Use Blockchain technologies and smart contracts (TE-5) to ensure secure and efficient trading.
- **Community Engagement**
  - Involve Community members deeply in the decision-making process to raise engagement levels.
  - Encourage public consultations and participatory decision-making processes.
  - Implement Nudging Apps (TE-14) for near real-time closed-loop consumer activation.
- **E-Mobility Services**
  - Provide EV charging stations and electric bus chargers to promote fossil fuel-free transportation services.
  - Develop alternative value streams through the E-Mobility Cooperative BM archetype.
  - Utilize V2G technology to increase flexibility in the electricity grid and use EVs as flexible assets.
  - Involve Community members as shareholders and decision-makers in e-mobility services.
- **Local Energy Market (LEM)**
  - Implement an LEM based on P2P trading to maximize self-sufficiency and minimize traded power volumes with external markets.
  - Allow market participants to negotiate trading conditions, such as pricing.
  - Ensure transparency by providing knowledge of the energy source, predominantly from solar PVs.
  - Distribute revenues between prosumers and consumers based on the difference between local and external market tariffs.
  - Ensure system reliability by signing agreements with the DSO and energy retailers.
- **Stakeholder Collaboration**
  - Collaborate with key partners including the municipality, public buildings, businesses, SMEs, the DSO, Bekscsaba Energia Esco Ltd., energy suppliers, technology, service, and mobility providers, and the public transit company.
  - Establish a mixed-use EnC with municipality-driven features.

2.4.6 Irish Pilot: Cross-sector social value community-centred services for enhancing grid flexibility and paving the way for increased share of self-sufficiency

The Irish pilot is intended to implement various TEs, which in return will affect the correlations between energy citizens and the Community itself.

- **Consumer and Community Engagement**
  - Implement TE-1 to provide consumers and external citizens access to economic, social, and environmental benefits.
  - Facilitate citizens' participation in public consultations and decision-making processes regarding the operation and profits of the EnC.
  - Ensure that citizens have direct access to relevant knowledge and information about the EnC.
- **Knowledge and Investment in New Technologies**
  - Deploy TE-2 to educate the EnC about new technologies and their potential value.
  - Inform community members about new business models and the benefits of shared assets and sharing mechanisms.
- **Social Engagement and Information Exchange**
  - Utilize TE-3 as a platform for social engagement and information exchange.
  - Link citizens to service providers and automate enrolment in utility flexibility and Demand Response (DR) services.
  - Ensure TE-3 integrates with TE-16 to support and educate citizens on low carbon and resilient energy solutions.
- **Data Management and Connectivity**
  - Implement TE-4 as an energy data space-compliant tool to ensure efficient data management.
  - Enable connectivity between all digital platforms to enhance community engagement and data sharing.
- **Data Security and Privacy**
  - Utilize TE-5 to increase end-user participation in personal energy data sharing, both individually and within the framework of a Data Cooperative.
  - Ensure data transfer and security to protect against GDPR violations, fostering trust and sovereignty among citizens.
- **Customer Clustering and Segmentation**
  - Apply TE-7 to strengthen community engagement through customer clustering and segmentation.
  - Use this tool to bundle behaviours and interpret socioeconomic characteristics of community segments.
- **Privacy-Preserving Demand Response**
  - Deploy TE-1a as a privacy-preserving tool for automated interoperable DR.
  - Ensure this tool is directed towards the EnC and its members to enhance engagement and participation.

2.5 Mapping Business Requirements/Use Cases

Active societal participation in the socio-energy transition is essential, extending beyond mere public acceptance or lifestyle changes. It is vital to foster energy citizenship, promoting ownership, democratization, decentralization, and community-based energy production. However, current social practices, technologies, and business models are not yet mature enough to fully enable energy citizenship. The main challenge lies in the existing business models, such as ESCO- and supplier-based models, which fail to recognize the value of active behaviour from individuals and communities. To address this, the ENPOWER project, particularly Task 2.5, proposed innovative hybrid private/public sharing economy business models that leverage shared ownership and management of community-level assets. These models aim to capture and distribute financial and non-financial benefits, including carbon emission reduction, improved comfort, and job creation.

To address these challenges, ENPOWER designed consumer-centric business models that consider EnCs as innovations as part of Task 2.5 and developed the corresponding Business Model Canvas (BMC) in D2.3 under Section titled: Definition and BM Concept Idea, where the framework explores the different dimensions of a business and clearly defines how value is generated across each dimension for each pilot site.

ENPOWER's business models and associated business requirements in pilot sites foster a diverse and inclusive ecosystem involving stakeholders at local, regional, and national levels. These new business models offer fully customized solutions tailored to the unique needs of individual energy consumers across six pilot cases, as described in D2.3

In the next section, we will link these consumer-centric business models to the technical requirements developed through High-Level Use Cases (HLUC) and Technical Enablers (TEs). These connections will illustrate how the proposed models support active societal participation and energy citizenship, addressing the current gaps in social practices, technologies, and business models.

The following Table 2 presents updated mapping for TEs per ENPOWER pilot site.

Table 2: Technology Enablers (TEx) in ENPOWER pilots.

TE #	TE Description	Pilot					
		Austria	Portugal	Greece	Ireland	Hungary	Spain
TE-1	Interactive decision support tool for EnC planning						
TE-2	SITEC-Sizing tool for EnCs						
TE-3	CRP social engagement management platform						
TE-4	Energy Data Space compliant tools for sovereign data management, sematic interoperability and exploitation						
TE-5	DLT/Blockchain/smart contracts* multi-purpose marketplace for increased Trust & Sovereignty and for P2P tokenised assets sharing and compensation						

TE-6	Digital Twins for consumer activation						
TE-7	Consumers clustering and segmentation tools						
TE-8	FATEC - Flexibility Assessment tool for EnCs						
TE-9	Self-consumption optimisation tool						
TE-10	Closed-loop optimal load control and intelligent monitoring of electric appl. for residential users						
TE-11	V2G-based flexibility management platform for providing incentives to communities of EV drivers						
TE-12	OSTEC-Optimised Scheduling Tool for EnCs						
TE-13	AI-Powered Virtual Energy Manager (WIS4Households)						
TE-14	Nudging Apps for near real time closed loop consumers activation						
TE-15	Blockchain-based hybrid coalition-based flexibility aggregation tool						
TE-16	P2P digital tools and platforms for consumer activation and social engagement						
TE-17	P2P energy markets designs and algorithms						
TE-18	Privacy preserving tools for automated interoperable DR						

3 Functional Specifications

3.1 Functional Specifications Overview

The ENPOWER project is designed to transform the European energy system into a decentralized, secure, and consumer-centric ecosystem. At its core, ENPOWER aims to empower citizens to become active participants in energy markets through advanced technological, social, and business frameworks. This section provides an overview of the functional specifications that drive the project's objectives and operational functionality.

The ENPOWER framework integrates various technological tools to activate energy citizens, facilitate data-driven community engagement, and optimise energy management. One of the primary goals is to turn passive consumers into proactive participants by leveraging a Social Framework that uses behavioural insights to create incentives for active involvement in energy markets. This is achieved through sophisticated engagement platforms and community-specific incentives tailored to the unique characteristics of different communities.

A significant component of the ENPOWER framework is its data-driven approach to community engagement. The project employs AI and data analytics to segment consumers and customize interactions, ensuring effective and efficient engagement. This is supported by advanced ICT solutions that help communities manage their energy resources more efficiently, promoting the transition towards sustainable energy practices.

The architecture of the ENPOWER platform is composed of several layers, each playing a crucial role in achieving the project's goals. The Data Acquisition and Integration Layer focuses on interfacing with the physical world through smart meters and IoT devices, collecting real-time data from diverse energy resources. This data is then standardized and pre-processed to ensure compatibility across different platforms within the ENPOWER framework.

At the heart of the platform is the Core Analytical Layer, which includes components for advanced data analytics and machine learning. These tools derive insights from collected data, supporting decision-making processes for energy management. Simulation and modelling capabilities are also part of this layer, allowing the prediction and optimisation of energy usage and production within communities.

The Decentralized Transaction and Management Layer uses blockchain technology to ensure secure, transparent, and efficient energy transactions. Smart contracts automate various operations, such as billing and energy trading, enhancing the reliability of the decentralised network. This layer supports peer-to-peer energy trading and decentralised energy resource management, crucial for the democratisation of energy management.

Community engagement is further facilitated through the Community Engagement and Interface Layer, which provides user-friendly interfaces for end-users and system operators. These interfaces support interaction and management of energy resources within a community, integrating feedback and incentivisation mechanisms to encourage active participation in energy saving and production initiatives.

Finally, the Integration and Compliance Layer ensures that all operations within the ENPOWER platform comply with regional and international energy regulations and standards. It focuses on maintaining high interoperability with existing and future energy systems and adhering to open standards to facilitate seamless integration.

The ENPOWER architecture is designed to be robust, scalable, and flexible, allowing for the integration of future technological advancements and regulatory changes. This architectural framework lays the foundation for deploying a range of applications and services that empower citizens and communities to actively participate in a decentralized, efficient, and sustainable energy ecosystem.

3.2 Analysis of ENPOWER Framework

The ENPOWER Framework is designed to orchestrate a transformative shift in energy systems, placing European citizens at the forefront as active participants and decision-makers. This initiative stands as a comprehensive response to the evolving demands for a sustainable, secure, and consumer-centric energy ecosystem.

Fundamentally, the ENPOWER framework integrates technological tools with the aim of:

- **Activate Energy Citizens**: Through the application of a Social Framework, the project targets the activation of citizens, turning passive consumers into proactive participants. This component focuses on leveraging behavioural insights to create incentives that promote active involvement in energy markets.
- **Facilitate Data-Driven Community Engagement**: By employing AI and data analytics, the framework segments consumers and customizes interactions, ensuring that community engagement is both effective and efficient.
- **Optimise Energy Management**: Utilizing cutting-edge ICT solutions, the framework aids communities in managing energy more efficiently, facilitating the transition towards sustainable energy practices.

A distinctive aspect of the ENPOWER project is its emphasis on integrating citizens not just as energy users but as vital stakeholders in the energy marketplace. This integration is achieved through:

- **Community-Specific Incentives:** The framework designs incentives tailored to the unique characteristics and needs of different communities, encouraging a shift from conventional energy consumption to active market participation.
- **Engagement Platforms:** Interactive tools and facilitation services are developed to engage citizens at various levels, from individual decision-making to community-wide planning and implementation.

The ENPOWER Framework is inherently aligned with the European Union's goals for energy sustainability and efficiency. It addresses these through:

- **Sustainable Business Models:** Innovative business models under the Business Sandbox component explore value stacking and sharing economy principles to sustain community engagement and economic viability.
- **Energy Democracy and Security:** By democratising energy management and optimising local energy resources, the framework enhances the security of supply and fosters resilience within communities.
- **Providing Blueprints for Replication:** The project develops comprehensive blueprints that facilitate the EU-wide replication of successful models.

- **Advising on Policy Development:** Through its Leadership Programme, ENPOWER offers guidance to regulatory bodies, helping to shape enabling frameworks that support community-friendly energy policies.

This expanded overview of the ENPOWER Framework highlights its multifaceted approach to transforming European energy systems by integrating technological innovation, citizen engagement, and sustainable practices into a cohesive model. This strategic formulation not only addresses the immediate project objectives but also sets a foundation for long-term impact and scalability across Europe.

3.3 Review of Previous Projects

Before beginning the analysis of user needs and describing all the technical specifications and subsequently the business specifications for the EMPOWER project, a careful review of previous projects, already funded by the European Commission and focused on related and continuous themes, was conducted. The goal was to gather all information that could be useful for the project, analyse the results achieved, and assess the conclusions and lessons learned. For this reason, a concise list of these projects, along with a summary of their objectives, is presented in this paragraph. Specific attention is dedicated to the approach all projects have dedicated to the system architecture.

3.3.1 BD4NRG

BD4NRG is a Horizon 2020 project funded by the EU, focusing on creating a platform that facilitates the sharing of data and services within the energy sector. This platform aims to standardise various existing methodologies to support a wide array of applications. The project's reference architecture was developed in two phases, starting with the analysis and evaluation of current models and methods, including BRIDGE, GAIA-X, IDS RAM, and FIWARE RA. The objective is to incorporate use cases from 12 BD4NRG pilot projects spanning 9 countries. The Reference Architecture was completed in July 2022, reflecting both technical advancements and feedback from ongoing pilot projects.

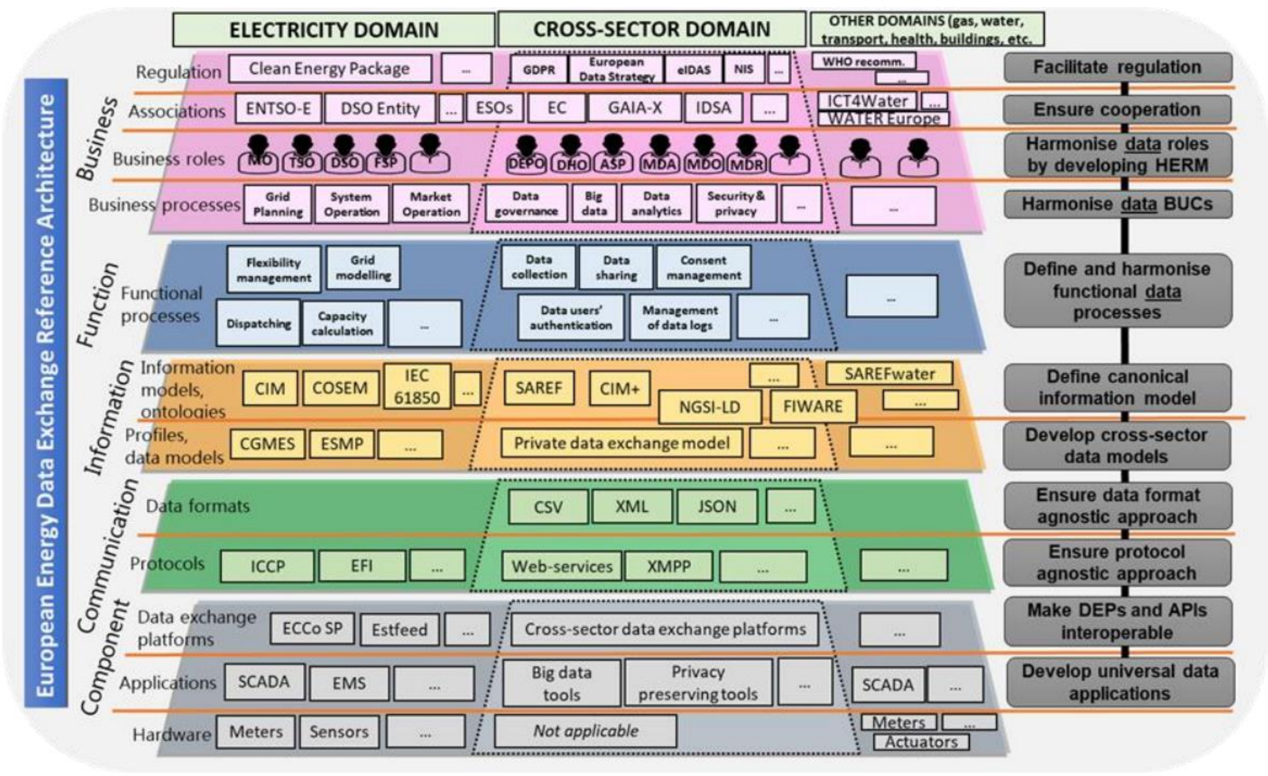

Figure 2: BD4NRG Reference Architecture [9].

As outlined in Figure 2, the BD4NRG reference architecture is structured on the BRIDGE RA framework, adapted to meet project-specific needs and integrating elements from IDSA, GAIA-X, and FIWARE. It comprises four primary layers and an additional pillar addressing cross-system aspects.

The **Data Sources** Layer concentrates on cataloguing and analysing Big Data from various sources such as energy sensors, SCADA systems, Building Energy Management systems, databases, and platforms, including environmental data. This layer encapsulates all the data-producing entities as described in the Component Layer of the BRIDGE architecture.

The **Data Interoperability** Layer deals with defining communication interfaces and data formats, and it proposes data and information models for data transformation to facilitate interoperable data exchanges.

The **Functional Layer** is divided into two sublayers: the "Innovative Data Analytics Toolbox" for developing analytics functions within BD4NRG, and a "Marketplace" above it for trading these functions. The "Marketplace" sublayer acts as the connection between BD4NRG functionalities and the business actors and ecosystems using them, handling tasks like Smart Contracts, Transaction Tracking, and Payment Facilitation.

The **Business Actors and Ecosystems** Layer identifies the different stakeholders involved in the data analytics and energy data spaces. These include data providers, users of analytics services, analytics application providers, and facilitators of data spaces, where an entity like a Transmission System Operator (TSO) might simultaneously be a data provider and consumer.

A right-hand-side pillar of the Reference Architecture extends through the system, encompassing three sections: "Data Space Governance," "Data Sovereignty & Trust"—which includes Identity

Management and Data Provenance—and "Data Space Levels" (Cloud, Edge, Fog), detailing their application within the system.

The practical deployment of the BD4NRG system and its architecture is ongoing, guided by insights from the pilots and incorporating IDSA and FIWARE components.

3.3.2 PlatONE

The Platone Open Framework is designed to establish a comprehensive, scalable system that facilitates mechanisms for managing distribution grid flexibility and congestion through peer-to-peer market models engaging various stakeholders across multiple levels (DSOs, TSOs, customers, aggregators). The development of the PlatONE Framework utilizes an iterative process, incorporating feedback from demonstration sites and lab tests to refine its design and implementation.

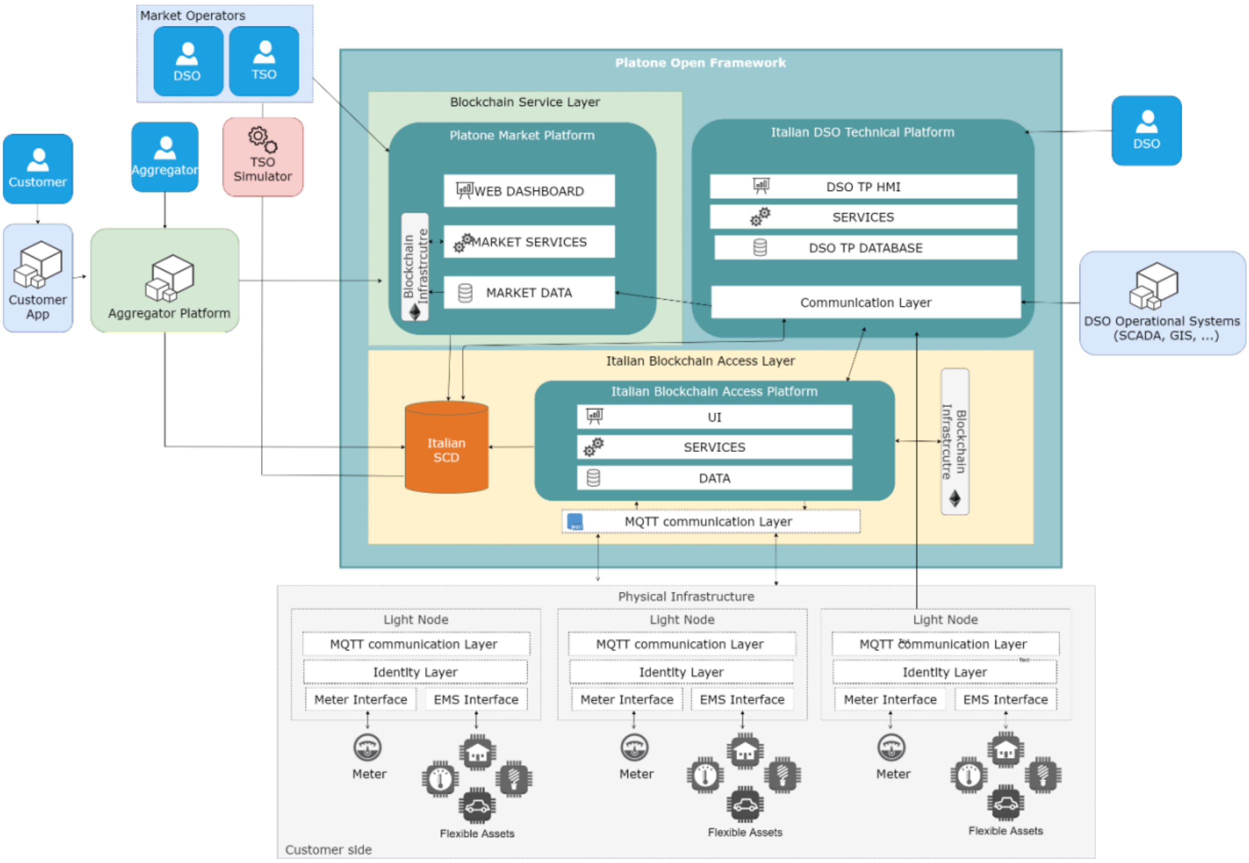

Figure 3: PlatONE Framework Applied to the Italian Demo [10].

In Figure 3, one can observe the different components and their internal makeup within the Platone Open Framework, specifically the subsystems for Blockchain Service Layer, Blockchain Access Layer, and the Platone DSO Technical Platform. The diagram also illustrates how these components interact with stakeholder infrastructures and the various systems stakeholders use to communicate and share data with the framework.

The following five platforms support the Local Flexibility Markets:

- Market Platform: This fundamental component utilises blockchain technology to record flexibility needs and requests, aligning aggregator offers with grid requirements based on specifications and rules established by the System Operators.

- Aggregator Platform: This component handles the management of flexible resources, optimising market strategies and flexibility offerings.
- Blockchain Access Layer: Ensures the platform's security and reliability, authenticating data from Light Nodes and managing Smart Contracts.
- Shared Customer Database: A repository for information, accessible only to authorised stakeholders in the Local Flexibility market.
- DSO Technical Platform: This platform executes crucial operations within market timelines, such as power flow management, flexibility requests, market outcome validations, and broadcasting setpoints to flexible resources.

PlatONE is contributing to the LFE SOGNO initiative, aiming for long-term sustainability and ensuring alignment with upstream projects that focus on open-source platforms for grid operators. As of the latest update, the final outcomes were scheduled to be presented in June 2023 at the LF Energy Summit in Paris, France.

3.3.3 OneNet

One of the objectives of OneNet is to establish an open and adaptable framework to evolve the European electricity system, which is typically controlled at a national level, into a more sophisticated and efficient network across Europe. The Reference Architecture depicted in Figure 4 is structured into three logical layers:

- The OneNet Participants layer allows secure and trusted access to data from various Data Sources for Energy Stakeholders, while ensuring data ownership and privacy.
- The OneNet Network of Platforms layer promotes the integration and collaboration of different platforms to provide services for both market and network operations. This includes various demonstration platforms like DSO platforms, Market platforms, and Data Exchange platforms, which can connect to the OneNet Middleware via the OneNet Connector.
- The OneNet Framework layer serves as a scalable and adaptable system to support platform cooperation and integration. It fosters a unique ecosystem where all energy stakeholders can engage.

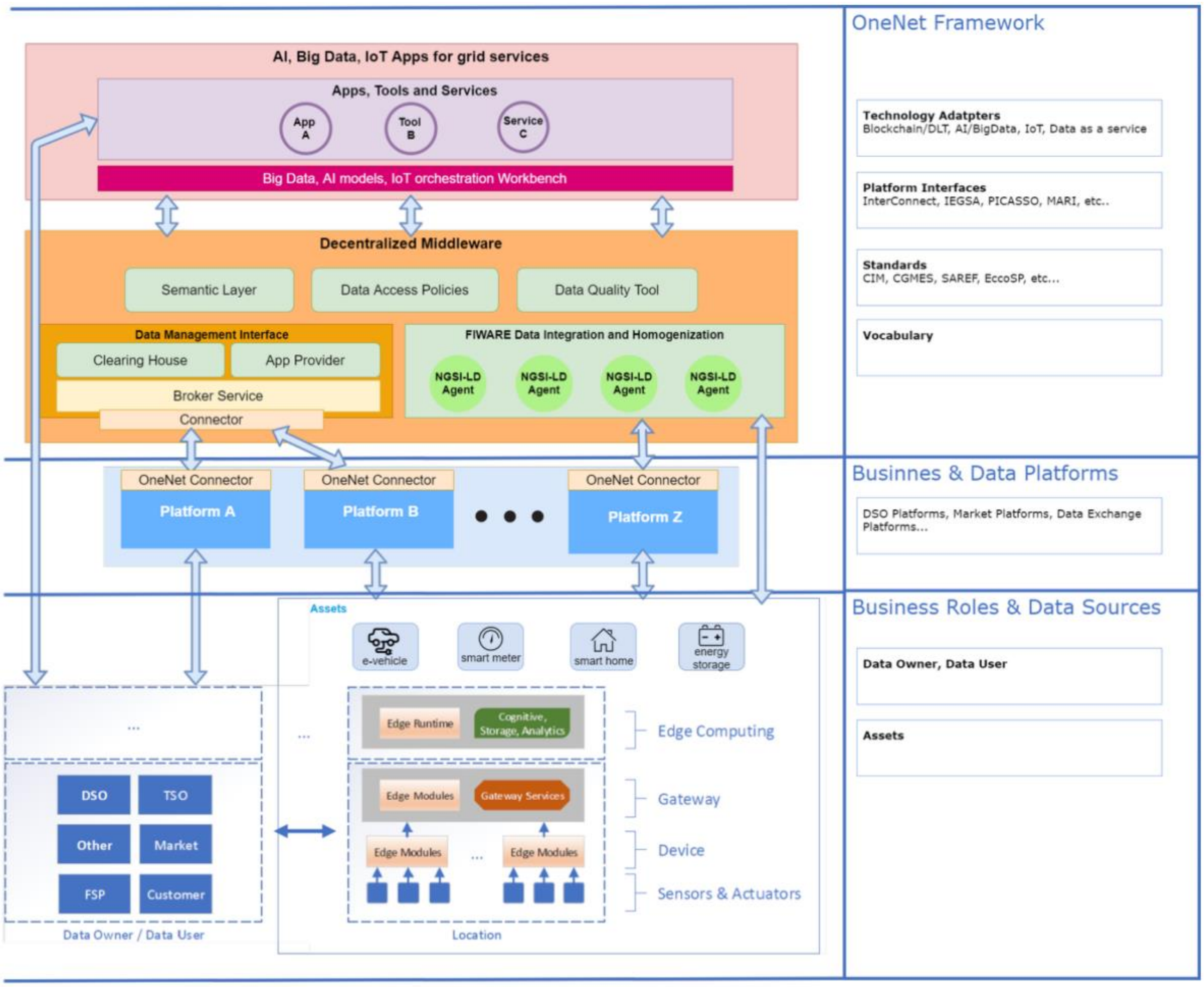

Figure 4: The OneNet Reference architecture [11].

The OneNet Participants layer comprises Data Sources and Energy Stakeholders:

- The Data Sources component includes all entities that generate or process data, sourced from various energy sectors like electric mobility, energy storage, and residential energy monitoring. These may include sensors, actuators, gateways, and edge computing nodes.
- The Energy Stakeholders component includes various market participants such as DSOs, TSOs, Market operators, and Customers, grouped into Service Providers, Data Consumers, and Data Providers, focusing on data exchange.

This layer interfaces directly with the OneNet Network of Platforms layer, providing a data foundation for business and data platforms as well as integrable services or applications. It connects to the OneNet Framework via the OneNet Middleware, using interoperability mechanisms based on the FIWARE Architecture and the FIWARE Orion Context Broker. Energy stakeholders also benefit from tools like the Orchestration Workbench for app testing and evaluation and can use analytics through the OneNet Monitoring Dashboard offered by the OneNet Framework.

The OneNet Network of Platforms layer emphasizes the seamless integration of external platforms—such as DSO platforms, market platforms, and other data exchange platforms—into the OneNet system through a fully decentralized approach. Here, two systems (OneNet Participants) can interact directly, bypassing third-party mediation. A critical element in this layer is the OneNet Connector, vital for facilitating the complete data exchange process and based on the IDS specifications and the FIWARE Orion Context Broker and NGSI-API, as depicted in Figure 5.

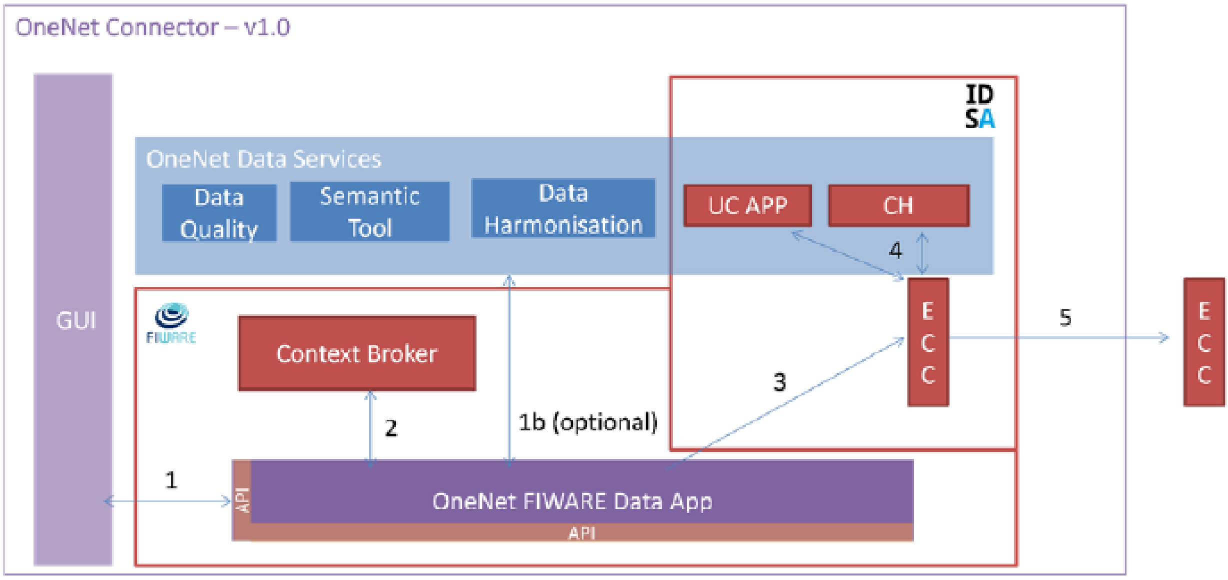

Figure 5: OneNet Connector Architecture.

The OneNet Framework layer, the cornerstone of the architecture, comprises the OneNet Decentralized Middleware, OneNet Orchestration Workbench, and OneNet Monitoring and Analytics Dashboard:

- The OneNet Middleware ensures secure, reliable data exchange among all integrated components, offering essential features like identity management and semantic annotation.
- The OneNet Orchestration Workbench supports data orchestration, evaluating AI, IoT, and Big Data services' performance and scalability across platforms for market and grid operations.
- The OneNet Monitoring and Analytics Dashboard acts as both an administrative and configuration tool, facilitating integration with the Orchestration Workbench and Middleware, and provides monitoring and alerting capabilities for data processes and platform integration.

3.3.4 BRIGHT

Figure 6 illustrates the comprehensive architecture of BRIGHT and how all its elements are coordinated and interact. To clarify this arrangement, four distinct layers or segments are discernible:

- **Service/Application Layer:** This segment encompasses the essential services of the BRIGHT system, where all the tools and applications facilitating the flexibility services are active.
- **Data Layer:** This layer organises and facilitates data sharing across different tools. It includes various data storage systems accessible within the system for tool utilization. Each storage system requires proper connectivity to effectively store and fetch data.
- **External Sources Layer:** This includes all the devices, gateways, metering infrastructures, or storage systems external to but necessary for the BRIGHT system. Examples include IoT devices, smart meters, weather data, EV stations, etc.
- **Interoperability Layer:** A unified communication method is essential due to the diversity of tools and data across different pilots and the need for scalability. BRIGHT incorporates an interoperable layer to establish standardized communication across the system. Key components of this layer include the message queue system for asynchronous communication and the external source connector, which standardizes the data entering and leaving the system.

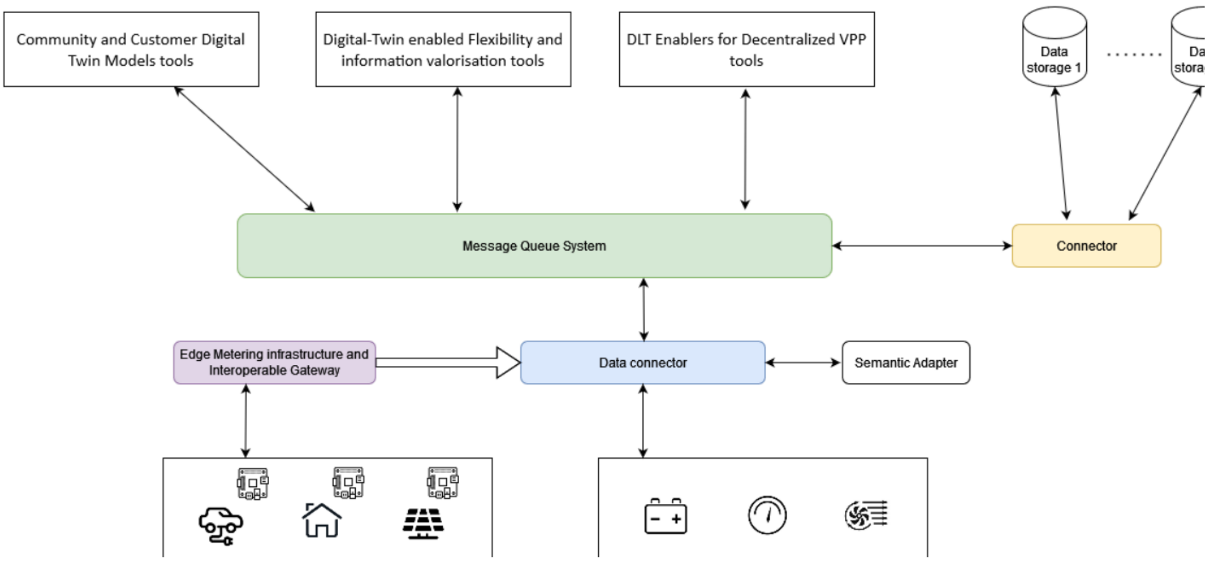

Figure 6: Conceptual BRIGHT's Architecture [12].

Service/Application Layer:

BRIGHT, being a complex and scalable application, adopts a microservices architecture for the service/application layer. This design allows each tool or component within the system to operate independently, focusing on specific tasks, and can be replicated as needed to manage requests and enhance scalability. This separation ensures that each tool can be developed independently with technologies suited to its specific service needs.

Data Layer:

External sources, such as IoT devices, inject data into the BRIGHT architecture using the message queue system. This data is processed by tools to fulfil specific objectives, with both the original and processed data potentially stored within the application's storage systems or a shared data repository. While tools are not obligated to use this layer's storage, it offers a convenient means of data sharing.

External Sources Layer:

This layer handles various data types like energy usage metrics and IoT device outputs, including weather forecasts. Entities within this layer may serve as both data providers and consumers. For instance, IoT devices might adjust settings automatically based on feedback from BRIGHT's flexibility services. Depending on the pilot and the particular environment, the entities in this layer can vary significantly. To standardize system communication, each external source must employ a proper interface, referred to in the architectural plan as a "data connector." A semantic adapter module aids this connector in normalizing information to align with a unified energy-related ontology such as SAREF.

Interoperability Layer:

Communication within BRIGHT is crucial and must adapt to varying data availability or service preferences influenced by the specific pilot environment. Additionally, data sources and tools may change as required. Thus, direct transmission between components is impractical. The chosen method is a messaging queue system, serving as the sole communication medium within BRIGHT. Components register on this bus as data providers or consumers. The system manages messages asynchronously, meaning that real-time communication is not the objective. Apache Kafka is the selected implementation for BRIGHT's messaging queue system.

3.3.5 eDREAM

eDREAM aims to create, test, and implement a decentralized, secure DR ecosystem that facilitates efficient collaboration between Distribution System Operators (DSOs) and aggregators to maximize the use of flexible energy resources across diverse and varied load and generation assets. Throughout the project, new functionalities and services will be explored and tested through the application of Internet of Things (IoT) principles, demand response strategies, and blockchain technology. The eDREAM platform's conceptual architecture is illustrated in Figure 7.

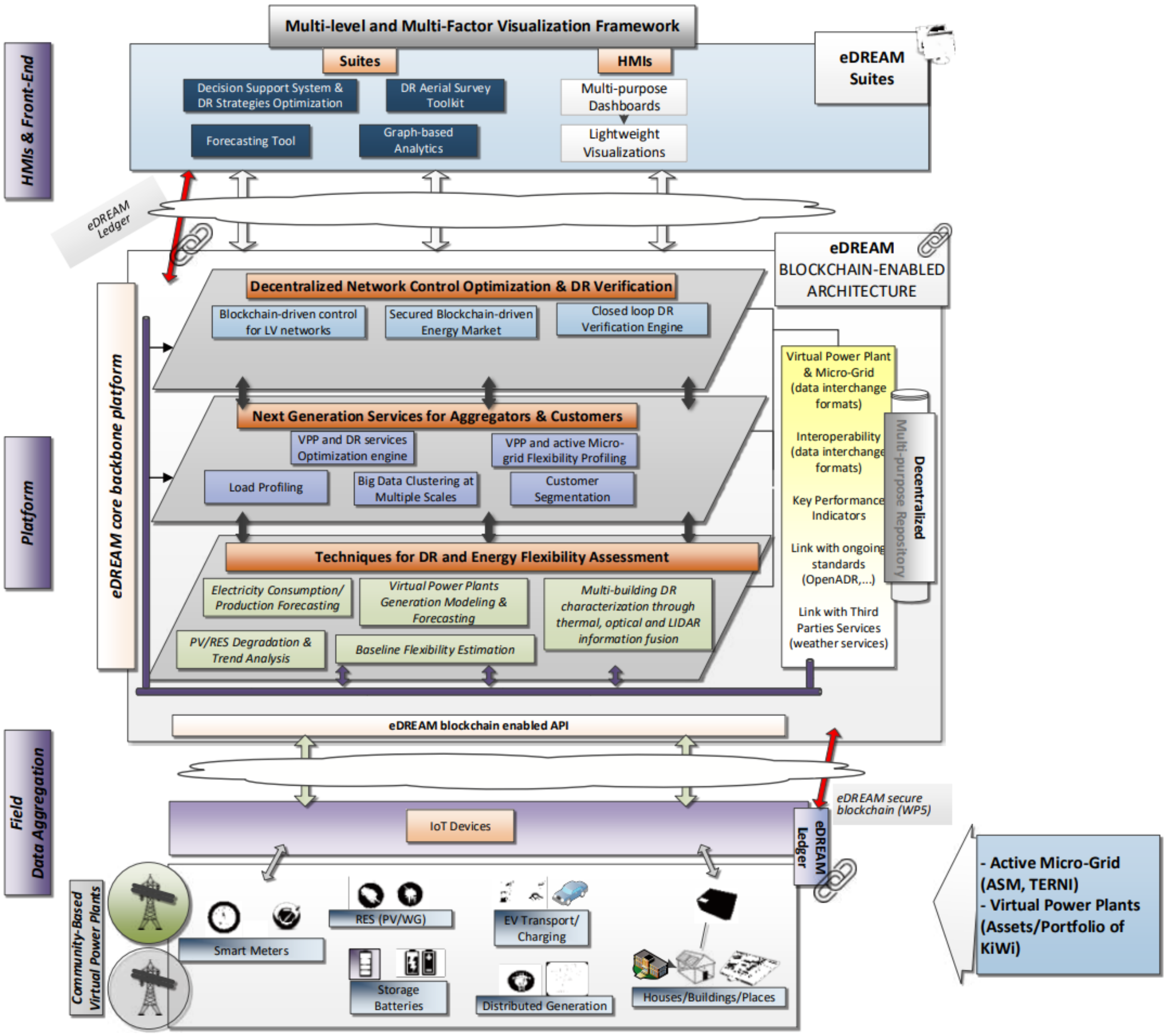

Figure 7: eDREAM Conceptual Architecture [13].

The essential layers and sub-layers of the eDREAM platform are briefly described as follows:

- The initial layer, Field Data Aggregation, acts as the point of contact with the physical realm through smart metering and communication interfaces. IoT devices collect real-time data from pilot sites, providing electrical measurements from devices within Microgrids and Virtual Power Plants (e.g., VPP data gathered through the KiWi smart gateway). This layer relays necessary real-time data to the platform's higher layers for analysis and computation. Data exchange is facilitated by open communication standards that support Machine-to-Machine (M2M) communications, enabling data, information, and commands to be sent to the correct field device or platform layer.
- The core of the architecture is the Core Backbone Platform, crucial for a decentralized ecosystem supporting closed-loop DR programs. This platform blends various components for research and development purposes to enhance services for system stakeholders. It comprises three interconnected hierarchical sub-layers linked to a Decentralized Multi-purpose Repository, detailed as follows:

- Techniques for DR and Energy Flexibility Assessment focus on developing advanced consumption and production forecasting methods for prosumers within the aggregator's portfolio, enhancing both short-term and long-term energy forecasts. The results aid various energy market programs like day-ahead and direct trading. Additionally, innovative methods for optimising distributed generation resource coalitions and aerial survey techniques for pre-evaluating new DR program customers will provide aggregators with critical business insights.
- Next Generation Services for Aggregators and Customers aims to equip system stakeholders (e.g., Aggregators, DSOs) with all necessary services for determining and extracting key features and parameters for customers/prosumers at different scales. This includes employing cutting-edge machine learning for load profiling and disaggregation, and a Big Data Analytics Engine for analysing vast data streams to identify customer clusters with specific load and generation profiles.
- Decentralized Network Control Optimisation & DR Verification focuses on using blockchain technology for DR modelling, distributed control, and validation. A blockchain distributed ledger will be established at the grid level to securely store energy transactions and DR services, while self-enforcing smart contracts will manage and control these transactions. Proof-of-Stake consensus algorithms will also be explored for DR program execution, verification, and financial settlement, alongside a Graph-based Analytics platform to automate and enhance DR programs.

- The upper layer, HMIs & Front-end for end-users and operators, features user-friendly interfaces (e.g., accessible on mobile devices) that enable both vertical and horizontal collaboration within the eDREAM framework. This layer visualizes and interprets data from the Core Backbone Platform, facilitating decision-making based on the analysis provided by the platform’s components.
- Lastly, the Core Platform connects with a Decentralized Multi-purpose Repository, which facilitates data exchanges within the eDREAM core framework. This component serves as a storage and maintenance hub for data from field devices, data models/profiles to support core component functions, and information from third-party services (e.g., weather services).

3.4 ENPOWER Functional Specifications

This section presents the technological specifications that serve as the foundation for the ENPOWER framework. The project utilizes advanced technologies to enable citizen participation in energy markets, optimize energy management, and support data-driven interactions within energy-secure communities. These specifications encompass a wide range of technological enablers, including AI-based tools, blockchain systems, digital twins, and energy data spaces, all aimed at achieving the project's goals.

The technological solutions are organized according to the High-Level Use Cases (HLUC) defined in Deliverable 2.1 “*Gap analysis and use case capitalisation towards a consumer-centric energy system*”, ensuring that each enabler addresses specific project objectives and community needs.

3.4.1 High Level Functional Specifications List

3.4.1.1 HLUC1: EnC clustering and segmentation

Title	Data Collection for Energy Profiling
Description	This function focuses on the systematic collection of data related to energy consumption, production, and storage within Energy Communities (EnCs), providing a foundational dataset necessary for effective energy management and analysis.
Functionality	• **Energy Consumption Data Collection:** Systematically gather detailed data on how much energy is consumed within the community, identifying peak usage times and potential inefficiencies. • **Energy Production Data Collection:** Record data on energy produced by community assets, such as solar panels or other renewable sources, to assess production efficiency and contribution to the community's energy needs. • **Energy Storage Data Collection:** Monitor the capacities and usage patterns of energy storage systems to understand their role in energy balancing and emergency back-up within the community.
Input data	• **Energy Consumption Data** • **Energy Production Data** • **Energy Storage Data**
Output data	• **Comprehensive Energy Profiles**: Detailed profiles that capture the energy consumption, production, and storage characteristics of the community. • **Usage and Efficiency Reports**: Reports that summarize the operational efficiency, potential areas for improvement, and overall energy management within the community.

Title	Data Integration Across Multiple Factors
Description	This functionality integrates socio-economic, geographic, socio-cultural, and socio-political information of EnCs to enhance the understanding of energy consumption patterns and facilitate targeted energy solutions tailored to specific community characteristics.
Functionality	• **Socio-economic Data Integration:** Aggregate and analyse demographic data such as age distribution, household size, and economic status of community

	members to tailor energy solutions to demographic trends. • **Geographic Data Integration:** Use geographic information systems to map the locations of community energy assets and residential areas, enhancing spatial analysis for energy planning and infrastructure development. • **Socio-cultural Data:** Collect and interpret data related to the cultural practices, values, and community behaviours that influence energy usage. This includes understanding local customs that may impact energy consumption patterns, such as holiday festivities or communal practices. • **Socio-political Data:** Analyse the political landscape, including local policies, regulations, and government programs that impact energy management.
Input data	• **Socio-economic Data** • **Geographic Data** • **Socio-cultural Data** • **Socio-political Data**

Title	**Energy Community Clustering**
Description	This functionality applies clustering algorithms to group similar EnCs based on predefined criteria such as energy usage patterns and other factors data. This categorization facilitates targeted energy management strategies and intervention planning.
Functionality	• **Application of Clustering Algorithms:** Use advanced clustering algorithms to categorize EnCs into similar groups based on multiple criteria, which may include energy consumption patterns, demographic information, and geographical data. • **Dynamic Grouping:** Allow for dynamic updating of groups as new data becomes available or as community characteristics change over time. • **Customization of Criteria:** Enable the customization of clustering criteria based on the specific needs or goals of the energy management initiatives.
Input data	• **Energy Data:** Detailed data on community energy consumption and production patterns. • **Other Factors Data:** Comprehensive information that includes socio-economic, socio-cultural, and socio-

	political factors along with geographic details that impact energy consumption and production, such as location relative to climate zones and community characteristics that may influence energy usage.
Output data	• **Clustered Groups of EnCs:** EnCs grouped by similarity in various aspects, providing a structured way to approach energy management.

Title	**Data Connectors**
Description	This functionality establishes robust interconnections between various data systems to ensure the integration and management of energy data from EnCs. This integration facilitates efficient data flow and access, enhancing data-driven decision-making.
Functionality	• **Integration with Smart Meters and IoT Devices:** Establish connections with smart meters and IoT devices to automatically collect real-time energy data, ensuring accurate and timely data availability. • **Connection with Energy Management Systems:** Link with energy management systems to utilize energy data for operational control, efficiency improvements, and demand response initiatives. • **Data Synchronization Across Platforms:** Ensure consistent and synchronized data across various platforms, preventing data discrepancies and facilitating comprehensive data analysis.
Input data	• **Real-Time Energy Data:** Continuous data streams from smart meters and IoT devices detailing energy consumption, production, and storage. • **System Operation Data:** Information from energy management systems related to energy usage patterns, system performance, and efficiency metrics.
Output data	• **Integrated Data Feeds:** A consolidated view of energy data from multiple sources, provided in a format suitable for analysis and reporting.

3.4.1.2 HLUC2: Flexibility assessment of EnC

Title	**Real-Time Flexibility Monitoring**

Description	This functionality focuses on monitoring the real-time energy usage and production within EnCs to assess their immediate flexibility potential. It enables the communities to quickly respond to changes in energy demand or pricing, optimizing their energy consumption and production in real-time.
Functionality	• **Continuous Data Monitoring:** Collect and analyse real-time data from smart meters and IoT devices to monitor current energy usage and production levels. • **Flexibility Assessment:** Assess the real-time flexibility potential of the community by evaluating their ability to increase or decrease energy usage or production at short notice.
Input data	• **Real-Time Energy Consumption Data:** Immediate data on how much energy is being consumed within the community. • **Real-Time Energy Production Data:** Data on the amount of energy being produced by community assets, such as solar panels or wind turbines.
Output data	• **Real-Time Flexibility Reports:** Reports detailing current flexibility potential, including possible adjustments in energy usage and production.

Title	**Historical Data Analysis**
Description	This functionality involves analysing past energy consumption and production data from EnCs to understand historical flexibility patterns and improve predictive models for future energy management strategies.
Functionality	• **Data Aggregation and Analysis:** Compile and analyse historical data on energy usage and production to identify trends, patterns, and variability in energy demands and responses. • **Trend Identification:** Identify long-term trends in energy flexibility, such as seasonal variations in energy usage or production peaks, which can inform strategic planning and operational adjustments. • **Predictive Model Enhancement:** Utilize historical data to enhance the accuracy of predictive models that forecast future energy needs and flexibility capacities.
Input data	• **Historical Energy Consumption Data:** Detailed records of past energy usage, including times of peak consumption and low usage periods.

	• **Historical Energy Production Data:** Data on the amounts of energy historically produced by the community, particularly from renewable sources.
Output data	• **Historical Flexibility Analysis Reports:** These reports consolidate insights from past energy consumption and production data, outlining historical flexibility patterns and trends. They include detailed analyses of peak and low usage periods, seasonal variations, and the effectiveness of past adjustments in energy management.

Title	**Flexibility Potential Analysis**
Description	This functionality assesses the capacity of EnCs to adapt their energy usage in response to external signals such as price changes or grid demands. It is crucial for effectively integrating renewable energy sources and managing demand response activities.
Functionality	• **Analysis of Flexibility Capacity:** Evaluate the ability of EnCs to adjust power usage, generation, and storage in response to external factors like grid requirements and economic incentives. • **Identification of Flexibility Opportunities:** Identify specific times and conditions under which EnCs can most effectively adjust their energy patterns to benefit both the community and the broader energy grid. • **Recommendation of Actionable Strategies:** Provide actionable strategies to EnCs on how to harness their flexibility potential to optimize energy costs and support grid stability.
Input data	• **Real-time and Historical Energy Consumption Data:** Current and past data on energy usage patterns within the community. • **Energy Pricing Information:** Current and forecasted energy prices that could influence flexibility strategies. • **Grid Demand and Supply Status:** Information about the overall demand and supply on the grid to determine when flexibility is most needed. • **Renewable Energy Generation Data:** Data on the amount of energy generated from renewable sources, which is often variable and can significantly influence flexibility strategies.

Output data	• **Flexibility Capacity Reports:** Detailed reports on the flexibility potential of each community, indicating how and when they can adjust their energy consumption or production. • **Optimization Recommendations:** Tailored recommendations for each community on optimizing energy usage to take advantage of pricing fluctuations and grid needs. • **Predictive Analyses and Scenario Simulations:** Outputs from models that simulate various scenarios to predict how changes in grid conditions or energy prices could affect the community's energy strategy.

Title	**Optimization of Flexibility Usage**
Description	This functionality develops strategies and tools to maximize the economic and operational benefits of flexibility within EnCs. It aims to optimize how these communities use their ability to adjust energy production and consumption in response to external factors like grid demands and price signals.
Functionality	• **Development of Flexibility Strategies:** Create tailored strategies that optimize energy usage based on the unique characteristics and capabilities of each EnC, focusing on maximizing economic benefits and supporting grid stability. • **Implementation of Optimization Tools:** Deploy advanced tools that automate the process of adjusting energy usage in real-time, based on algorithms that consider multiple factors including energy prices, grid demand, and renewable energy availability. • **Continuous Optimization Process:** Establish a continuous feedback loop where energy usage data and external signals are constantly analysed to refine and improve flexibility strategies.
Input data	• **Real-Time Pricing Data:** Current electricity prices that can influence when and how energy should be consumed or stored. • **Grid Demand Signals:** Signals from the grid operator indicating times of high demand where flexibility can be utilized to stabilize the grid. • **Energy Production and Consumption Data:** Continuous input on how much energy is being produced and consumed within the community.

Output data	• **Optimized Energy Schedules:** Detailed schedules that specify optimal times for energy consumption and production, aiming to reduce costs and assist the grid. • **Economic Benefit Analysis:** Analysis of the financial benefits achieved through optimized flexibility usage, including cost savings and potential revenue from energy sales or grid services.

Title	**Demand Response Strategy Implementation**
Description	This functionality focuses on implementing DR strategies within EnCs to enhance their ability to respond dynamically to grid demands and energy pricing fluctuations. This strategic implementation enables EnCs to capitalize on economic incentives while aiding grid stability during peak and off-peak periods.
Functionality	• **Development of DR Strategies:** Create demand response strategies that allow EnCs to adjust their energy usage in response to signals from energy providers or grid operators. • **Real-Time Response Capabilities:** Equip communities with the tools and systems needed to respond in real-time to demand response signals, ensuring timely adjustments to energy consumption or production. • **Performance Monitoring and Adjustment:** Monitor the effectiveness of deployed DR strategies and make necessary adjustments based on performance data and evolving grid needs.
Input data	• **Grid Demand Signals:** Information from grid operators indicating the need for demand response actions, such as requests to reduce or increase energy consumption during specific times. • **Energy Pricing Fluctuations:** Data on real-time and forecasted energy prices that impact the cost-effectiveness of participating in demand response programs. • **Community Energy Usage Profiles:** Detailed profiles of energy usage within the community, which help in tailoring demand response actions.
Output data	• **Demand Response Compliance Reports:** Reports detailing the community's response to demand signals, including adjustments made and the impact on energy consumption and costs.

3.4.1.3 HLUC3: Digital Twins for consumer-aware optimal flexibility planning

Title	**Optimization of Energy Flexibility**
Description	This functionality focuses on optimizing the deployment of flexible energy resources within EnCs to maximize efficiency, reduce costs, and enhance grid stability. It leverages advanced optimization algorithms to dynamically manage the distribution and consumption of energy based on real-time data and predictive models.
Functionality	• **Flexible Resource Allocation:** Dynamically allocate energy resources such as storage systems, demand response capabilities, and DERs to where they are most needed, based on real-time grid conditions and forecasts. • **Real-time Demand and Supply Balancing:** Utilize predictive analytics and real-time data to adjust energy supply from renewables and demand from consumers to maintain grid balance and avoid overloads or energy wastage. • **Energy Efficiency Maximization:** Implement optimization strategies that ensure energy is used at its highest efficiency across the community, reducing overall energy costs and environmental impact.
Input data	• **Real-time Energy Consumption Data:** Immediate and comprehensive data from community energy meters to monitor and respond to current energy usage patterns. • **Renewable Energy Production Forecasts:** Predictions on the output from renewable energy sources within the community, such as solar or wind, which can vary significantly due to weather conditions. • **Grid Demand Forecasts:** Projections of broader grid demand to anticipate periods of high or low demand, which can influence optimal energy resource deployment.
Output data	• **Optimized Resource Deployment Plans:** Detailed strategies for the allocation and use of energy resources to meet the community's needs while optimizing for cost and efficiency. • **Energy Savings Reports:** Documentation of energy and cost savings achieved through optimized energy management, supporting ongoing improvement and justification for energy strategies.

Title	**Integration of Digital Twins in Energy Management Systems (EMS)**
Description	This functionality integrates Digital Twins (DTs) with Energy Management Systems (EMS) to enable real-time management and optimization of energy resources in EnCs. DTs serve as virtual replicas of physical assets and systems, providing a platform for simulation, analysis, and optimization of energy flows within the community based on live data.
Functionality	• **Real-time Data Synchronization:** Seamlessly integrate real-time operational data from various energy assets within the community into the DTs, ensuring that the virtual models are always aligned with their physical counterparts. • **Energy Optimization:** Utilize DTs to simulate and implement optimal energy distribution and consumption strategies, taking into account current grid conditions, renewable energy production, and community energy demands. • **Predictive Maintenance and Fault Detection:** Leverage the predictive capabilities of DTs to foresee potential system failures or maintenance needs, thereby minimizing downtime and enhancing system reliability.
Input data	• **Operational Data from Energy Assets:** Includes real-time data from DERs, consumption patterns of the community, and status reports from energy storage systems. • **Grid Condition Data:** Information on current grid status, energy prices, and demand-response signals from grid operators. • **Weather and Renewable Forecast Data:** Predictive data concerning weather conditions and expected outputs from renewable energy sources, which can significantly affect energy production and consumption.
Output data	• **Optimized Energy Management Strategies:** Detailed strategies for the optimal use of energy within the community, aimed at reducing costs and maximizing the use of renewable resources. • **Energy Savings and Efficiency Reports:** Comprehensive analysis of energy savings achieved through optimized strategies, including efficiency improvements and reduced dependency on external power sources.

Title	Scenario Analysis for Demand Response (DR)
Description	This functionality leverages digital twin technology to analyse various DR scenarios and their potential impacts on energy consumption and grid stability within EnCs. It supports strategic planning by simulating responses to different demand response triggers and evaluating the effectiveness of these strategies.
Functionality	• **Demand Response Scenario Simulation:** Simulate various DR scenarios to understand how different triggers such as peak load pricing, grid emergencies, or renewable availability might affect community energy behaviours and grid interactions. • **Effectiveness Evaluation of DR Strategies:** Analyse the effectiveness of various DR strategies in managing peak loads and optimizing community energy consumption, helping to identify the most beneficial strategies for both consumers and the grid. • **Customization of DR Programs:** Tailor DR programs to the specific characteristics and needs of the community, based on the outcomes of scenario simulations, ensuring maximum participation and effectiveness.
Input data	• **DR Trigger Conditions:** Information about potential conditions that would initiate demand response events, such as high energy prices, peak demand times, or significant shifts in renewable energy production. • **Community Energy Usage Profiles:** Historical and real-time data on energy usage patterns within the community, which help to predict how the community might respond to different DR scenarios. • **Grid Requirements and Constraints:** Data on grid operational constraints and requirements, which demand response measures need to meet or alleviate.
Output data	• **DR Strategy Performance Reports:** Detailed assessments of each tested DR strategy, indicating their effectiveness in reducing peak loads, managing energy costs, and maintaining grid stability. • **Optimized DR Plans:** Recommendations for optimized demand response plans tailored to the community's characteristics and energy goals, including timing, expected participation rates, and expected impact on the grid. • **Impact Forecasts on Grid and Community:** Predictions on how effective demand response utilization will affect

	both the community's energy profile and broader grid stability.

Title	Cross-Sector Asset Management
Description	This functionality involves managing and coordinating various energy and non-energy assets across multiple sectors within EnCs to enhance energy flexibility and system resilience. It leverages digital twin technology to create integrated models that predict and optimize the operation of these assets in a cohesive manner.
Functionality	• **Integrated Asset Coordination:** Manage and synchronize the operation of diverse assets, such as solar panels, battery storage, Electric Vehicles (EVs), and HVAC systems, to optimize overall energy efficiency and reliability. • **Flexibility Optimization:** Utilize digital twins to model and predict the flexibility potential of various assets, facilitating their optimal use in response to energy demand, supply fluctuations, and market opportunities. • **Maintenance and Performance Tracking:** Implement predictive maintenance strategies and continuous performance monitoring to maximize the lifespan and efficiency of assets while minimizing downtime and operational costs.
Input data	• **Asset Performance Data:** Real-time and historical data on the performance and usage patterns of various assets within the community, essential for effective management and optimization. • **Energy Demand and Supply Forecasts:** Forecasts of local energy demand and renewable energy supply to align asset operation with energy availability and community needs. • **Market and Regulatory Information:** Information on energy market dynamics and regulatory constraints that might influence the strategic deployment of assets.
Output data	• **Asset Management Plans:** Comprehensive strategies for the coordinated operation and maintenance of cross-sector assets to meet community energy goals efficiently. • **Flexibility Utilization Reports:** Analysis of how effectively the managed assets contribute to energy

	flexibility, including metrics on improved energy efficiency and reduced costs. • **Maintenance Schedules and Alerts:** Predictive maintenance schedules and real-time alerts for asset servicing, based on performance monitoring and predictive analytics.

Title	**Monetization of Flexibility**
Description	This functionality focuses on developing and implementing strategies to monetize the energy flexibility of consumers within EnCs. It utilizes digital twin technology to model and simulate scenarios where energy flexibility can be capitalized through market mechanisms or incentive-based programs, enhancing the economic benefits for community members and considering opportunity costs.
Functionality	• **Flexibility Market Participation:** Develop strategies for participating in energy markets to sell excess energy or flexibility services, such as demand response, to grid operators or through P2P energy trading platforms. This includes evaluating the opportunity costs of not utilizing assets for alternative uses. • **Incentive Program Development:** Design and simulate incentive programs that reward consumers for their contributions to grid stability and efficiency, encouraging ongoing participation in energy flexibility initiatives. Consider the opportunity costs associated with participating versus not participating in these programs. • **Economic Impact Analysis:** Conduct comprehensive analyses to assess the financial impacts and opportunity costs of various flexibility monetization strategies, ensuring they align with community goals and market conditions.
Input data	• **Energy Flexibility Availability:** Data on the availability and capacity of energy flexibility within the community, including potential for load shifting, energy storage, and renewable energy generation. • **Market Prices and Demand:** Current and forecasted market prices for energy and flexibility services, as well as demand levels in local and regional markets.
Output data	• **Flexibility Revenue Models:** Detailed models and forecasts of revenue potential from selling flexibility

	services, providing a clear understanding of economic benefits and opportunity costs. • **Performance Metrics of Incentive Programs:** Metrics and data on the performance of incentive programs, demonstrating their effectiveness in motivating participants and providing financial rewards, alongside the opportunity costs involved. • **Strategic Recommendations:** Tailored recommendations for optimizing flexibility monetization strategies, based on economic analyses, market trends, and comprehensive evaluation of opportunity costs.

Title	**Performance Assessment via KPIs from DT**
Description	This functionality focuses on assessing the performance of EnCs by utilizing Key Performance Indicators (KPIs) derived from DTs. By analysing these KPIs, stakeholders can evaluate the effectiveness of implemented strategies and make informed decisions to further optimize energy management.
Functionality	• **KPI Definition and Tracking:** Define relevant KPIs such as energy efficiency, grid reliability, and cost savings, and track them using data collected from DTs. • **Performance Analysis:** Analyse KPI trends over time to assess the impact of different energy management strategies on overall performance. • **Benchmarking and Comparison:** Compare the performance of EnCs against industry standards or similar communities to identify areas for improvement and best practices.
Input data	• **Digital Twin Data:** Data collected from Digital Twins, including energy consumption, production, storage, and grid interactions. • **External Benchmarking Data:** Industry benchmarks and performance metrics for energy management and sustainability.
Output data	• **KPI Reports:** Regular reports detailing the performance of EnCs based on defined KPIs, providing insights into areas of success and areas for improvement. • **Trend Analysis:** Analysis of KPI trends over time, highlighting patterns and identifying factors influencing performance. • **Recommendations for Improvement:** Recommendations for optimizing energy management

	strategies based on KPI analysis and benchmarking results.

3.4.1.4 HLUC5: Community Centred Services

Title	**Energy Planning Tools Integration**
Description	This functionality integrates advanced energy planning tools, specifically the SITEC tools and the DT models from HLUC3, to enable comprehensive scenario assessment and optimal sizing of energy assets for EnCs. It leverages data-driven insights to propose well-informed energy management strategies that enhance energy efficiency and sustainability within communities.
Functionality	• **Scenario Assessment:** Utilizes integrated tools to evaluate various energy production and consumption scenarios, helping to forecast future energy needs and plan accordingly. • **Optimal Asset Sizing Recommendations:** Provides recommendations on the size and type of energy assets (e.g., solar panels, batteries, wind turbines) that best meet the community's energy goals considering economic, environmental, and technical factors. • **Flexibility Analysis:** Analyses the flexibility of energy assets to adjust to changing energy demands and supply conditions, enhancing the community's ability to respond to grid demands and maximize the use of renewable energy sources.
Input data	• **Community Energy Consumption Data:** Detailed records of current and historical energy consumption patterns within the community. • **Asset Performance Data:** Information on the performance metrics of existing energy assets, including efficiency rates and operational status. • **External Energy Market Data:** Data on energy prices, peak demand times, and renewable energy availability, to inform scenario planning.
Output data	• **Optimal Asset Configuration Reports:** Detailed reports outlining recommended configurations and sizes of energy assets based on the analysed scenarios. • **Energy Management Strategy Document:** A comprehensive strategy document detailing how to implement the recommended asset configurations to meet energy goals.

	• **Flexibility Potential Overview:** An assessment report of the community's energy flexibility potential with recommendations on how to improve it.

Title	**Advanced Forecasting Techniques Implementation**
Description	This functionality implements advanced forecasting techniques using machine learning (ML) and deep learning (DL) models to enhance the accuracy of predictions in energy management within EnCs. It supports decision-making processes by providing precise forecasts of energy demand and supply, optimizing the operation of energy assets and the overall energy efficiency of the community.
Functionality	• **Energy Demand Forecasting:** Utilizes ML and DL models to predict energy demand patterns in the community, allowing for better alignment of energy supply and conservation efforts. • **Energy Supply Forecasting:** Forecasts energy production from renewable sources like solar and wind, accounting for variability due to weather conditions and other factors. • **Model Training and Refinement:** Continuously trains and refines forecasting models using new data inputs to improve accuracy over time.
Input data	• **Historical Energy Consumption Data:** Past data on energy usage patterns within the community to train predictive models. • **Renewable Energy Production Data:** Historical data on energy output from community-owned renewable assets (e.g., solar panels, wind turbines). • **Weather and Environmental Data:** Information on local weather conditions, which significantly impact renewable energy production and energy consumption patterns.
Output data	• **Demand Forecast Reports:** Detailed forecasts of future energy demand in the community, with breakdowns by time of day, season, and other relevant factors. • **Supply Forecast Reports:** Predictions of energy production from renewable sources, helping to plan for periods of high or low production. • **Model Performance Metrics:** Reports on the accuracy and reliability of the forecasting models, providing insights into areas for improvement.

Title	Cross-Sector Asset Planning
Description	This functionality focuses on the integration of both energy and non-energy assets in the planning processes of EnCs. It facilitates cross-sectoral asset planning by evaluating technical, economic, and social impacts, ensuring comprehensive strategies that optimize asset utilization and enhance community resilience and sustainability.
Functionality	• **Open-Source Modelling:** Utilizes open-source software tools to model energy scenarios and asset integrations across different sectors, such as electric vehicles and heating systems. • **Pre-Feasibility Studies:** Conducts initial feasibility assessments to evaluate the viability and impact of integrating new assets within the community's existing infrastructure. • **Integration Scenarios Development:** Develops various integration scenarios to demonstrate how different assets can be combined to optimize energy efficiency and operational resilience.
Input data	• **Existing Asset Data:** Information on current assets, including type, capacity, and performance metrics. • **Community Infrastructure Data:** Details about the community’s infrastructure that would support or limit the integration of new assets. • **Economic and Market Data:** Economic data including cost, potential subsidies, incentives, and energy market trends that impact asset planning.
Output data	• **Integration Scenario Reports:** Comprehensive reports outlining various asset integration scenarios with evaluations of their feasibility and potential impacts. • **Economic Impact Analysis:** Analysis of the economic implications of different integration scenarios, including ROI estimates and cost-benefit analysis. • **Strategic Asset Planning Guide:** A strategic guide for implementing the optimal integration scenario, including timelines, expected outcomes, and key performance indicators (KPIs).

Title	Self-Optimisation Tool for Consumers

Description	This functionality offers a self-optimisation tool designed to enhance the decision-making capabilities of consumers within Energy Communities (EnCs). It provides automated, data-driven suggestions for optimizing energy consumption, helping consumers make informed choices about their energy use to improve efficiency and reduce costs.
Functionality	• **Consumption Pattern Analysis:** Analyses individual and community-wide energy consumption patterns to identify inefficiencies and potential savings. • **Automated Optimization Suggestions:** Generates automated suggestions for consumers to adjust their energy usage based on real-time data and predictive analytics. • **User Engagement Interface:** Includes an interactive interface that allows consumers to view their energy consumption patterns, receive suggestions, and track the impact of implemented changes.
Input data	• **Real-Time Energy Usage Data:** Continuous data feed of energy consumption from smart meters and sensors within the community. • **User Preferences and Settings:** Input from consumers regarding their preferences, such as preferred comfort levels and times of energy use. • **Energy Tariff Information:** Current energy prices and tariff structures to calculate potential savings from suggested optimization actions.
Output data	• **Optimization Reports:** Detailed reports on potential energy savings and efficiency improvements for individual consumers and the community as a whole. • **User Impact Statements:** Statements detailing the environmental and financial impact of changes made by consumers following the optimization suggestions. • **Engagement Metrics:** Data on user interaction with the optimization tool, including frequency of use and adjustments made based on suggestions.

Title	**Operational Management Tools**
Description	This functionality focuses on deploying operational management tools to enhance the effectiveness of energy asset utilization within Energy Communities (EnCs). It leverages tools like TE-9 and OSTEC, integrating them into the community's energy management system to optimize the scheduling and

	operation of flexible assets, thereby improving overall energy efficiency and operational reliability.
Functionality	• **Scheduling of Flexible Assets:** Utilizes advanced scheduling algorithms to manage the operation of flexible energy assets like storage systems, electric vehicle charging stations, and HVAC systems to maximize efficiency. • **Real-Time Data Processing:** Processes real-time data from various sensors and meters to dynamically adjust asset operations based on current energy demand and supply conditions. • **Operational Efficiency Analysis:** Analyses operational data to identify inefficiencies and areas for improvement in the management of energy assets.
Input data	• **Asset Operation Data:** Information on the operational status, capacity, and schedules of all flexible assets within the community. • **Real-Time Consumption and Production Data:** Continuous feed of energy consumption and production data from community assets and renewable energy sources. • **Environmental and Grid Conditions:** Data on current environmental conditions and grid demands that influence energy asset operation.
Output data	• **Asset Scheduling Reports:** Detailed schedules for the operation of flexible assets, tailored to maximize efficiency and meet community energy needs. • **Operational Performance Metrics:** Key performance indicators and metrics that assess the efficiency and effectiveness of asset operations. • **Recommendations for Operational Adjustments:** Insights and actionable recommendations for optimizing asset performance and energy management strategies.

Title	**Integration of Heating and Cooling Assets**
Description	This functionality explores the integration of heating and cooling systems into the energy management strategy of Energy Communities (EnCs). It involves developing scenarios to understand the impact of integrating these assets on the overall energy efficiency, sustainability, and cost-effectiveness of the community's energy system.

Functionality	• **Scenario Development:** Develops various scenarios for the integration of heating and cooling systems, considering different technological options and community layouts. • **Impact Analysis:** Assesses the potential impacts of integrating heating and cooling assets on the community's energy profile, including energy savings, cost implications, and environmental benefits. • **Strategy Recommendations:** Provides strategic recommendations based on scenario analyses, advising on the best approaches for integrating these assets into the community's existing energy system.
Input data	• **Current Heating and Cooling Load Data:** Data on existing heating and cooling demands and how they are currently met within the community. • **Technology Performance Data:** Information on the performance of various heating and cooling technologies that could be integrated into the community. • **Community Layout and Infrastructure Data:** Details about the community's physical layout and existing infrastructure to evaluate the feasibility of integrating new assets.
Output data	• **Scenario Analysis Reports:** Detailed reports outlining the outcomes of different integration scenarios, highlighting the pros and cons of each. • **Environmental Impact Assessments:** Assessments of the environmental impacts associated with different heating and cooling integration strategies. • **Strategic Implementation Plans:** Comprehensive plans that detail how to implement the chosen heating and cooling integration strategies, including timelines, budget estimates, and expected outcomes.

3.4.1.5 HLUC6: P2P renewable marketplace for energy and flexibility demand

Title	**Participant Registration and Profile Management**
Description	This functionality provides a secure and user-friendly interface for participants to register and manage their profiles in the P2P renewable marketplace. It facilitates the identification and authentication of participants, ensuring that only authorized users can access and operate within the marketplace.

Functionality	• **User Registration:** Allows new participants to register by providing required details such as name, contact information, role (producer/consumer), and payment details. Includes validation of email addresses and phone numbers. • **Profile Customization:** Participants can update their profiles with additional information like preferred trading preferences, notification settings, and energy production/consumption data. • **Authentication and Security:** Implements secure login mechanisms, including multi-factor authentication, to protect participant accounts and personal information. • **Role-based Access Control:** Defines different roles within the platform (e.g., administrator, consumer, producer) and ensures users can only access features relevant to their roles.
Input data	• **Personal Identification Information:** Name, address, contact details. • **Financial Information:** Bank account details, and payment gateways for transactions. • **Operational Preferences:** Details about energy production capacity or consumption patterns.
Output data	• **Registration Confirmation:** Emails or SMS confirming successful registration. • **Profile Updates:** Notifications about successful profile updates or required additional information.

Title	**Energy Supply Offers Management**
Description	This functionality enables consumers to manage their energy demands within the P2P renewable marketplace efficiently. It facilitates consumers in expressing their energy requirements, selecting offers, and managing their consumption preferences and strategies.
Functionality	• **Demand Expression:** Allows consumers to specify their energy needs, including type of energy, quantity, preferred pricing, and usage timings. • **Offer Selection:** Provides tools for consumers to browse available energy offers, compare different options based on price, type, and supplier ratings, and select the most suitable offer.

	• **Consumption Planning:** Helps consumers plan their energy consumption based on their schedules, budget constraints, and available offers. • **Demand Flexibility Management:** Enables consumers to participate in demand response programs by adjusting their consumption during peak and off-peak periods in response to incentives.
Input data	• **Energy Requirements:** Detailed specifications of energy needs (type, quantity, preferred times, etc.). • **Budget Constraints:** Information on the consumer's budget for energy purchases. • **Flexibility Preferences:** Consumer preferences for participating in demand flexibility initiatives.
Output data	• **Selected Offers:** Details of the energy offers chosen by the consumer. • **Consumption Schedules:** Planned energy consumption schedules based on selected offers. • **Participation Confirmations:** Confirmations of participation in demand response and other flexibility programs.

Title	**Flexibility Trading Platform**
Description	This functionality enables the trading of flexibility services such as demand response capabilities and energy storage within the P2P renewable marketplace. It provides a platform where flexibility can be offered, bought, and managed to enhance grid stability and optimize energy use.
Functionality	• **Flexibility Offer Creation:** Allows providers (consumers, energy storage operators) to list available flexibility services, including adjustable consumption, energy storage capacity, and emergency power supply capabilities. • **Flexibility Demand Posting:** Enables grid operators and other consumers to post their requirements for flexibility services to maintain grid balance or meet specific energy needs. • **Nudging DR:** Automates the matching process between available flexibility offers and demands based on parameters such as response time, capacity, and price.

	• **Transaction Management:** Handles the contractual and financial aspects of flexibility service transactions, including confirmation, billing, and settlement.
Input data	• **Service Details:** Information about the flexibility service being offered, such as capacity, duration, response time, and price. • **Demand Requirements:** Specifications of the flexibility needed, including the amount of power, duration, and preferred pricing.
Output data	• **Match Results:** Details of matched flexibility offers and demands.

Title	**Notification of Activation Requests**
Description	This functionality facilitates the communication and management of activation requests for flexibility services within the P2P renewable marketplace. It ensures timely and effective notification to service providers when their flexibility services are activated.
Functionality	• **Activation Request Issuance:** Enables grid operators or other market participants to issue requests for activating flexibility services as per the requirements of the grid or market conditions. • **Notification Dispatch:** Automatically sends notifications to flexibility service providers about the activation requests, detailing the specifications and expected performance parameters. • **Provider Response Handling:** Collects and manages responses from service providers regarding their ability to meet the activation request, including confirmation or declination.
Input data	• **Request Details:** Information about the activation request, including the type of flexibility needed, quantity, timing, and any specific conditions or requirements. • **Provider Availability:** Status updates from providers about their current ability to respond to activation requests.
Output data	• **Activation Notifications:** Alerts sent to providers detailing the activation requirements. • **Response Summaries:** Summaries of responses from providers, including confirmations and declinations.

Title	Aggregated Energy Production Forecast
Description	This functionality provides forecasting of aggregated energy production for the participants in the P2P renewable marketplace. It aids energy producers in planning and optimizing their energy output and assists market operators in managing supply levels effectively. Additionally, it includes financial benefits for energy producers resulting from improved market conditions, as larger production volumes are better valued by energy traders.
Functionality	• **Data Collection and Analysis:** Collects real-time and historical production data from various energy producers to analyse trends and patterns. • **Forecast Modelling:** Utilizes advanced predictive modelling techniques to forecast future energy production based on various factors like weather conditions, historical production data, and market demands. • **Integration with Market Operations:** Ensures that forecast data is integrated with market operation tools for real-time decision-making and optimization.
Input data	• **Historical Production Data:** Past production records from various energy sources. • **Market Demand Data:** Information on current and anticipated energy demand in the marketplace.
Output data	• **Production Forecasts:** Detailed forecasts of expected energy production over various time frames. • **Recommendation Reports:** Suggested actions for energy producers based on forecast outcomes. • **Impact Analyses:** Analyses of potential impacts of forecasted production on market prices and grid stability.

Title	Activation Confirmations and Schedule Optimization
Description	This functionality manages the confirmation of activation requests for flexibility services and optimizes schedules for activated services within the P2P renewable marketplace. It ensures timely acknowledgment of activation requests and maximizes the effectiveness of flexibility services.

Functionality	• **Activation Confirmation:** Provides a mechanism for flexibility service providers to confirm their ability to meet activation requests promptly. • **Schedule Optimization:** Optimizes the schedules of activated flexibility services to align with grid requirements, market demands, and provider capabilities. • **Real-time Adjustments:** Allows for real-time adjustments to activation schedules based on changing grid conditions, market dynamics, and participant preferences.
Input data	• **Activation Requests:** Requests for activating flexibility services, including details such as timing, duration, and quantity. • **Provider Availability:** Availability status and capacity of flexibility service providers to meet activation requests. • **Market Demand:** Current market demand and grid requirements for flexibility services.
Output data	• **Confirmation Notifications:** Notifications confirming the successful activation of flexibility services. • **Optimized Schedules:** Updated schedules for activated flexibility services, reflecting adjustments based on real-time conditions. • **Performance Reports:** Reports on the performance and effectiveness of activated flexibility services, including metrics such as response time and reliability.

3.4.1.6 HLUC7: Nudging for near real-time EnC consumers activation

Title	Real-time Consumer Activation via Nudging Apps
Description	This functionality leverages interactive nudging apps to prompt and guide EnC members to modify their energy usage behaviours in real-time. It aims to enhance consumer responsiveness to energy pricing signals, grid demands, and renewable energy availability, fostering more sustainable and efficient energy use.
Functionality	• **Behavioural Modification Prompts:** Use nudging apps to deliver personalized messages and prompts that encourage users to adjust their energy usage based on real-time data. • **Adaptive Recommendations:** Provide dynamic, situation-aware recommendations that adapt to current

	grid conditions and individual user profiles, maximizing both energy savings and consumer comfort. • **User Engagement Tracking:** Monitor user interactions and responsiveness to nudging prompts to refine strategies and increase effectiveness over time.
Input data	• **Real-time Energy Pricing Data:** Information on current energy prices to enable cost-effective usage adjustments. • **Consumer Usage Patterns:** Data on individual energy consumption patterns, used to tailor nudging prompts to each user's habits and preferences. • **Grid Demand and Supply Status:** Data on grid load and renewable energy generation levels to align consumer behaviour with grid optimization needs.
Output data	• **Behavioural Change Reports:** Summaries of how nudging apps have influenced user behaviour, including adjustments in consumption times and reductions in peak load contributions. • **User Response Analytics:** Analytics on user engagement levels with the apps, including interaction rates and behaviour change success rates.

Title	User-Centred Interface Design for Various End-Users
Description	This functionality involves developing intuitive and accessible user interfaces tailored to the specific needs of different end-users within Energy Communities (EnCs). The aim is to facilitate effective interaction and engagement with the energy management systems, enhancing user experience and participation in energy conservation and optimization efforts.
Functionality	• **Customizable Interface Layouts:** Design adaptable interface layouts that can be customized according to user roles and preferences, such as for building managers, residential users, and grid operators. • **Role-Based Access and Features:** Implement role-based access control systems to ensure that users have access to relevant features and data necessary for their specific energy management tasks.
Input data	• **User Role Data:** Information about the user's role within the EnC, used to tailor the interface and available functionalities.

	• **User Preferences and Settings:** Data on individual preferences for interface layout, notifications, and other settings that enhance personalization and usability. • **Energy Consumption and Production Data:** Real-time and historical data on energy consumption and production, accessible via the interface to inform users and support decision-making.
Output data	• **Personalized Interface Configurations:** User-specific interface settings and configurations that enhance the user experience and engagement with the energy management system. • **Usage Reports and Dashboards:** Customizable reports and dashboards that display relevant energy data and analytics, helping users make informed energy management decisions.

3.4.1.7 HLUC8: Flexibility management providing incentives to communities of EV drivers

Title	EV Charging Management Platform Integration
Description	This functionality integrates an advanced management platform to oversee and optimize electric vehicle (EV) charging within Energy Communities (EnCs). It allows for the efficient coordination of EV charging stations, enhancing the overall energy management capabilities of the community. This system is pivotal in balancing local energy demand with supply, particularly in leveraging renewable energy sources and peak demand management.
Functionality	• **Charging Station Coordination:** Manages the operation of multiple EV charging stations within the community, ensuring optimal usage and avoiding overloads during peak times. • **Integration with Renewable Energy Sources:** Synchronizes charging times with the availability of renewable energy generation, such as solar or wind power, to maximize the use of clean energy. • **User Access and Control:** Provides EV owners with user-friendly access to charging station reservations, status updates, and usage history through a mobile app or web interface.
Input data	• **EV Charging Demand Data:** Information on the current and projected charging requirements of the community's EVs.

Output data	• **Optimized Charging Schedules:** Detailed schedules that coordinate EV charging with renewable energy availability and electricity pricing.

Title	Real-Time Data Handling for EV Charging
Description	This functionality focuses on managing and processing real-time data related to electric vehicle (EV) charging within Energy Communities (EnCs). It enables the optimization of charging processes in response to various dynamic factors such as grid demands, availability of renewable energy, and EV usage patterns. This functionality supports efficient energy resource management by adapting EV charging activities to real-time conditions, thereby enhancing grid stability and energy utilization.
Functionality	• **Dynamic Data Acquisition:** Capture real-time data from EV charging stations and vehicles to continuously monitor charging activities and energy usage. • **Adaptive Charging Strategies:** Develop and implement adaptive charging algorithms that respond to changes in grid conditions and renewable energy availability to optimize energy consumption and cost. • **Real-Time Analytics:** Analyse incoming data in real-time to make informed decisions about charging schedules and load distribution among EVs.
Input data	• **EV Charging Data:** Real-time data from EV charging stations, including current charge levels, charging speed, and expected completion times. • **Grid Demand Data:** Information on current grid load and forecasts to adjust charging loads accordingly.
Output data	• **Optimized Charging Schedules:** Automated schedules that adjust based on real-time data to optimize energy usage and costs. • **Energy Consumption Reports:** Detailed reports on energy consumption and efficiency for each EV charging session. • **Load Management Insights:** Analytical insights into how EV charging impacts the overall energy load and suggestions for improving grid stability and efficiency.

Title	Management of Future Reservations at Charging Stations

Description	This functionality allows Energy Community (EnC) members and external users to reserve EV charging slots at community charging stations in advance. It manages scheduling and availability, ensuring optimal utilization of charging infrastructure. This system aims to streamline access to charging facilities, reduce wait times, and balance the charging load across available stations based on forecasted demand and user preferences.
Functionality	• **Reservation System Integration:** Implement a user-friendly interface that allows drivers to view available charging slots and book them in advance through a mobile app or web portal. • **Demand Forecasting:** Utilize predictive analytics to forecast charging demand and dynamically adjust the availability of reservation slots to optimize charging station utilization. • **User Preference Management:** Allow users to set preferences for charging times and station locations, which the system will consider when allocating reservations.
Input data	• **User Reservation Requests:** Data from users requesting charging slots, including preferred times and station preferences. • **Charging Station Availability Data:** Real-time and forecasted data on the availability of charging stations and their operational status. • **Historical Charging Data:** Data on past charging patterns to aid in forecasting future demands and managing peak loads.
Output data	• **Reservation Confirmations:** Confirmation messages sent to users about their booking status, including time slots and station details. • **Utilization Reports:** Reports on the utilization rates of charging stations, highlighting peak times and underused periods. • **Demand Management Insights:** Insights into charging patterns that help in planning additional infrastructure or adjusting existing capacities.

Title	Load Management Strategies: Load Valley Filling
Description	This functionality involves the strategic management of electric vehicle (EV) charging loads to enhance grid stability and

	efficiency. Load valley filling specifically targets the off-peak hours to increase electricity consumption, reducing the impact of fluctuating demand on the grid. By encouraging EV charging during these periods, this approach helps to stabilize the grid and ensures a more consistent utilization of energy resources.
Functionality	• **Off-Peak Charging Promotion:** Encourage EV charging during off-peak hours through financial incentives or lower tariffs, aligning with periods of low grid demand. • **Automated Scheduling:** Utilize automated systems to schedule EV charging during predetermined off-peak hours, ensuring adherence to load valley filling strategies without manual intervention. • **User Preferences Integration:** Allow users to opt into off-peak charging plans that align with their schedules and mobility needs, providing flexibility while maintaining grid efficiency.
Input data	• **Grid Demand Forecasts:** Predictions of grid demand fluctuations that help determine optimal times for load valley filling. • **Tariff Information:** Data on variable electricity tariffs, which can be used to incentivize off-peak charging. • **User Scheduling Preferences:** Inputs from users regarding their typical vehicle usage patterns and availability for charging.
Output data	• **Charging Schedules:** Customized charging timelines for each participating EV, distributed to maximize grid stability during low-demand periods. • **Incentive Utilization Reports:** Analysis of the uptake and effectiveness of incentives offered for off-peak charging. • **Grid Impact Analysis:** Reports detailing the impact of load valley filling strategies on overall grid performance, demonstrating shifts in peak load and improvements in energy utilization.

Title	Vehicle-to-Grid (V2G) Transaction Facilitation
Description	This functionality supports the integration of electric vehicles (EVs) as active components of the grid, enabling them not only to draw power but also to return energy back to the grid during peak demand times. V2G transaction facilitation manages and optimizes these interactions, enhancing grid resilience and

	allowing EV owners to benefit financially by contributing to grid stability.
Functionality	• **Bi-directional Charging Management:** Enable and manage the flow of electricity both to and from EVs, adapting to grid needs and vehicle usage patterns. • **Demand Response Coordination:** Coordinate with grid operators to use EVs as mobile energy resources during critical peak periods or when renewable generation is low.
Input data	• **Grid Energy Demand Data:** Real-time data on grid energy demands to identify when it is most beneficial to draw energy from EVs. • **Energy Pricing Data:** Current energy prices, which influence the financial viability of drawing power from EVs during peak times. • **Vehicle Availability Data:** Information from EV owners about their vehicle's availability for participating in V2G services, ensuring that vehicle use is not compromised.
Output data	• **Energy Contribution Reports:** Details on the amount of energy each participating EV has contributed to the grid, used for billing and analysis. • **Financial Compensation Details:** Summary of financial benefits received by EV owners for their contributions to grid stability. • **System Performance Metrics:** Data on the overall performance of the V2G system, including its impact on grid stability and renewable energy utilization.

Title	Incentivization Mechanisms for Schedule Shifts and Discharge
Description	This functionality develops and implements strategies to incentivize electric vehicle (EV) owners within Energy Communities (EnCs) to adjust their charging schedules and participate in discharge activities during peak demand times. By offering incentives, this system encourages behaviour that supports grid stability and optimizes community energy costs and consumption patterns.
Functionality	• **Dynamic Incentive Structuring:** Create and manage a dynamic incentive system that adjusts offers based on grid needs and renewable energy availability. • **User Engagement and Behavioural Insights:** Utilize behavioural analytics to tailor incentives to individual

	user patterns and preferences, increasing participation rates. • **Feedback and Reward System:** Provide immediate feedback and rewards to users for participating in scheduled shifts and discharge activities, reinforcing positive behaviour.
Input data	• **Grid Load and Demand Forecasts:** Data on expected grid load and peak demand times to plan incentive offerings effectively. • **User Participation History:** Historical data on user responses to incentives, used to refine and personalize future offers. • **Renewable Energy Production Data:** Information on current and forecasted production from renewable sources, which can influence the timing and nature of incentives.
Output data	• **Incentive Utilization Reports:** Analysis of how incentives are used and their effectiveness in shifting charging behaviours. • **Energy Savings and Cost Reduction Reports:** Detailed reports showing the impact of incentive-driven schedule shifts on energy consumption, cost savings, and grid stability. • **User Engagement Statistics:** Metrics on user participation rates and satisfaction, helping to gauge the success of the incentive mechanisms.

Title	User Interface Development for EV Drivers
Description	This functionality involves the creation of an intuitive and user-friendly interface for electric vehicle (EV) drivers within Energy Communities (EnCs). The interface provides EV drivers with easy access to information about their charging schedules, energy usage, and available incentives. It facilitates interaction with the smart charging systems and enhances the user experience by making complex data easily understandable and actionable.
Functionality	• **Real-Time Information Display:** Provide EV drivers with real-time information about their current charging status, expected charge completion times, and any changes to scheduled charging due to grid demands or incentive offers. • **Interactive Scheduling Features:** Allow drivers to adjust their charging schedules through the interface,

	responding to changes in electricity rates or availability of renewable energy. • **Customization and Preference Settings:** Enable users to set preferences for notifications, charging times, and participation in incentive programs directly through the interface.
Input data	• **Charging Station Data:** Status and availability of charging stations, including any scheduled maintenance that might affect availability. • **Electricity Pricing Data:** Current and forecasted electricity prices. • **Incentive and Reward Information:** Details of current incentives for adjusting charging times or participating in grid services.
Output data	• **User Adjustments and Preferences:** Records of user adjustments to their charging schedules and set preferences for future interactions. • **Notification and Alert Histories:** Log of all notifications and alerts sent to the user, including confirmations of schedule adjustments and reminders about available incentives. • **Usage Statistics and Trends:** Compiled data on the user's charging habits and responses to different interface features, used to improve the system and interface design.

3.4.2 ENPOWER Architecture overview

This chapter provides an overview of the ENPOWER platform conceptual architecture, introducing the major layers, sub-layers, and architectural components of the ENPOWER platform. ENPOWER aims to create a decentralised, secure, and consumer-centric energy system that facilitates active citizen engagement and cross-sector community integration for sustainable energy use. Throughout the project, novel functionalities and services will be researched and examined, utilising advanced Information and Communication Technologies (ICT), social and behavioural sciences, and innovative business models.

This high-level conceptual architecture serves as an initial overview of the ENPOWER platform. Detailed architectural specifications and refined components will be further developed and documented in future deliverables, such as D4.1.

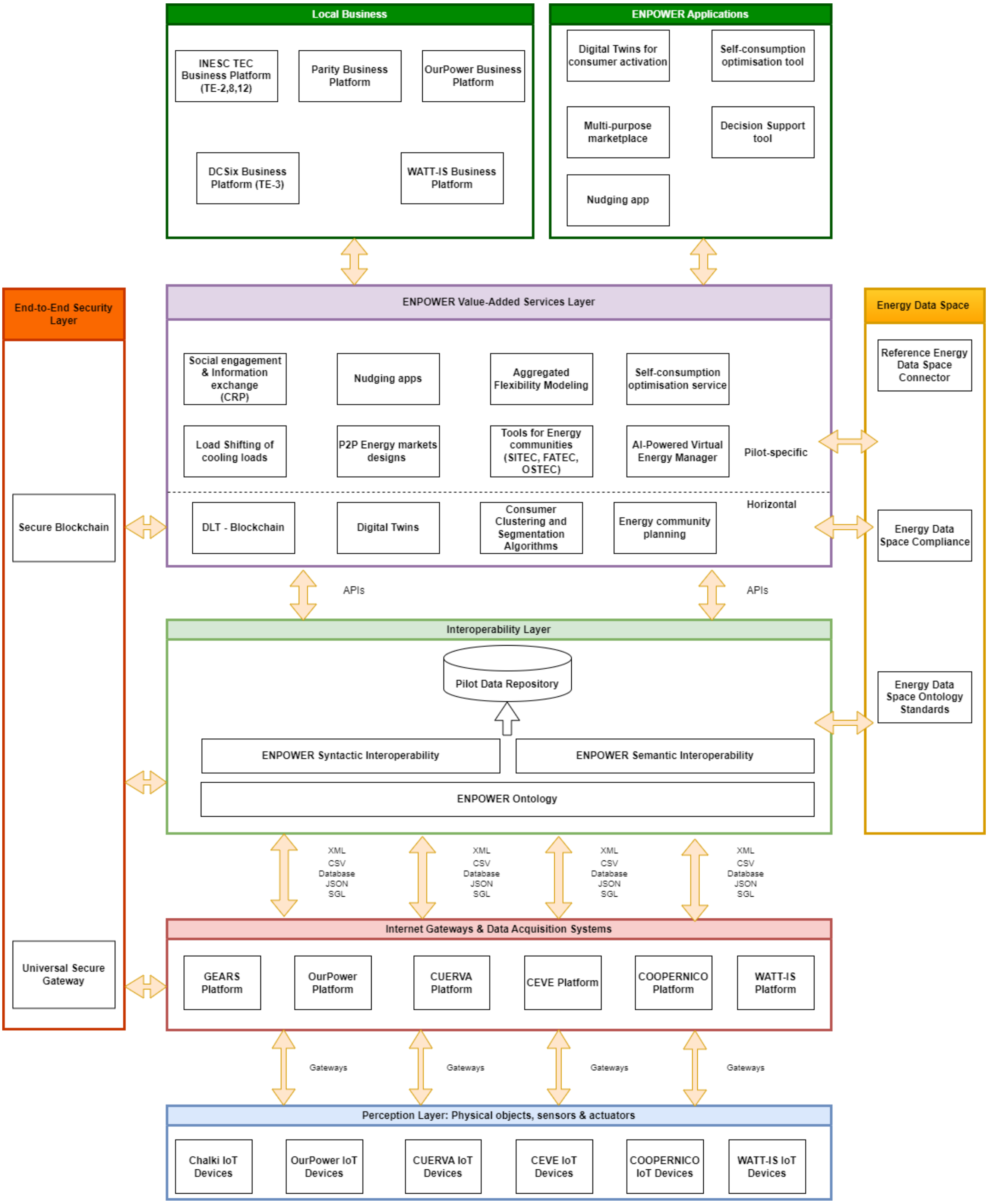

Figure 8: ENPOWER Architecture Overview.

The conceptual architecture of the ENPOWER consists of several layers and sub-layers, each playing a crucial role in achieving the project's objectives, as depicted by Figure 8. These are described briefly below:

- **Perception Layer**
    - **Physical objects, sensors & actuators**: This layer includes IoT devices from various platforms (Chalki, OurPower, CUERVA, CEVE, COOPERNICO, WATT-IS) that collect real-time data.
- **Internet Gateways & Data Acquisition Systems**
    - **Gateways:** These facilitate data transmission from the IoT devices to the platforms.
    - **Platforms:** GEARS, OurPower, CUERVA, CEVE, COOPERNICO, WATT-IS platforms collect and manage data from the respective IoT devices.
- **Interoperability Layer**
    - **Pilot Data Repository:** Stores data for further processing.
    - **ENPOWER Ontology:** Provides a common framework for data interpretation.
    - **Syntactic and Semantic Interoperability:** Ensures consistent data exchange and understanding across different systems.
- **ENPOWER Value-Added Services Layer**
    - **Pilot-Specific:** Provides tailored tools and models for social engagement, energy flexibility, P2P market designs, and consumer segmentation.
    - **Horizontal:** Offers nudging apps, self-consumption optimisation, AI-powered energy management, and digital twin technologies for energy communities.
- **Local Business**
    - **INESC TEC Business Platform (TE-2,8,12)**
    - **Parity Business Platform**
    - **OurPower Business Platform**
    - **DCSix Business Platform (TE-3)**
    - **WATT-IS Business Platform**
- **ENPOWER Applications**
    - **Digital Twins for consumer activation**
    - **Self-consumption optimisation tool**
    - **Multi-purpose marketplace**
    - **Decision Support tool**
    - **Nudging app**
- **Energy Data Space**
    - **Reference Energy Data Space Connector**: Ensures integration with external data sources.
    - **Compliance and Standards**: Ensures data meets industry standards for interoperability and security.
- **End-to-End Security Layer**

- **Secure Blockchain**: Provides security for transactions and data integrity using blockchain technology.
- **Universal Secure Gateway**: Ensures secure data transmission across the system.

- **APIs**
  - Facilitate communication and data exchange between different layers and components.

The ENPOWER architecture is designed to be robust, scalable, and flexible, allowing for the integration of future technological advancements and regulatory changes. This architectural framework lays the foundation for deploying a range of applications and services that empower citizens and communities to actively participate in a decentralised, efficient, and sustainable energy ecosystem. This chapter sets the stage for detailed descriptions of each component and their interactions, as presented in the subsequent chapters of the documentation.

All project partners have not run the architecture presented in this chapter. This draft will be subject to further review and modifications based on feedback and testing from all participating parties.

3.5 ENPOWER Business Specifications

The ENPOWER framework aims to transform business interactions within the energy sector by introducing innovative, consumer-centric business models and fostering an ecosystem where different stakeholders can collaborate effectively. This transformation is vital for achieving the project's goals of increasing energy efficiency, sustainability, and community engagement. The following key elements define the business interactions within the ENPOWER framework:

Innovative Business Models

ENPOWER leverages novel business models rooted in the sharing economy and social innovation. These models facilitate new market roles and interactions by:

- Engaging Energy Communities and Prosumers: Developing shared ownership models for renewable energy generation and storage assets. These models reduce upfront costs and increase consumer activation by allowing collective investment and benefit sharing.
- Balancing Financial and Non-Financial Benefits: Capturing and propagating both financial gains and non-financial benefits such as social cohesion, job creation, and improved business efficiency. This holistic approach ensures that community members see tangible benefits from their participation in the energy market.

Interactive Tools and Platforms

To support these innovative business models, ENPOWER provides interactive tools designed for community planning and consumer activation:

- Decision Support Tools: These tools help consumers and communities plan their energy use, assess various scenarios, and make informed decisions. The tools incorporate gamification strategies to enhance user engagement and facilitate the transition from passive consumers to active prosumers.
- Facilitation Services: These services assist in setting up, planning, developing, and managing energy communities. They also support optimal interaction with energy grids and other vectors, ensuring that the community's energy behaviours and decisions are well-informed and effective.

Data-Driven Services and Marketplaces

ENPOWER promotes the use of data-driven services and blockchain-based digital marketplaces to streamline and enhance business interactions:

- Consumer Data and Privacy: Implementing privacy-preserving federated learning environments and interoperable automated DR systems. These systems ensure consumer data is used efficiently while maintaining privacy and security.
- Tokenized Energy Marketplaces: Developing a P2P digital marketplace using blockchain technology to facilitate trading energy and non-energy assets. This marketplace allows for real-time, fair, and transparent transactions, making it easier for small consumers to participate in the energy market.

Engagement and Co-Creation

A significant aspect of ENPOWER's business interactions is the engagement and co-creation with stakeholders:

- Stakeholder Workshops and Training: Conducting workshops and training sessions to educate stakeholders about the benefits of ENPOWER services. These sessions are crucial for building trust and ensuring that stakeholders are fully informed about the new business models and tools.
- Co-Creation Sessions: Actively involving over 1,500 stakeholders in co-creation sessions to design multi-dimensional incentives and business models that align with the unique needs and preferences of different communities.

By integrating these elements, the ENPOWER framework not only enhances existing business interactions but also creates new opportunities for collaboration and innovation within the energy sector. This comprehensive approach ensures that all stakeholders, from individual consumers to large organizations, can benefit from and contribute to a more sustainable and efficient energy system.

4 Conclusion

The present deliverable (D2.4) sets the baseline for future architectural elaborations and implementation activities within the ENPOWER project. It captures the vision of various stakeholders involved in the development of a consumer-centric, data-driven, and community-focused energy system. This includes outlining the primary modules of the proposed framework and introducing the conceptual structure that will guide the ongoing development and refinement of the project.

The ENPOWER project represents a significant step forward in the transformation of Europe's energy systems, driven by the integration of cutting-edge technologies, innovative business models, and active citizen participation. As the energy landscape shifts towards a more decentralized and consumer-centric approach, ENPOWER serves as a blueprint for how communities can take control of their energy needs while contributing to broader sustainability goals.

The project's framework, which combines technical innovations such as AI, blockchain, digital twins, and data-driven tools, ensures that energy communities can operate efficiently and securely. By empowering citizens to engage as active participants in energy markets and decision-making processes, ENPOWER promotes energy democracy, increases local energy security, and supports the European Union's ambition for a sustainable energy future.

Furthermore, ENPOWER's business specifications create pathways for long-term economic viability through peer-to-peer energy trading, innovative value-sharing models, and the facilitation of decentralized marketplaces. The combination of these business models with advanced technical solutions ensures that energy communities will not only thrive locally but also serve as replicable examples across Europe.

As the project progresses through its pilots and further development phases, ENPOWER is poised to demonstrate how citizen engagement, technological advancement, and business innovation can collectively create resilient, sustainable, and secure energy systems. The project's outcomes will offer valuable insights for policy makers, energy providers, and communities, ultimately leading to more inclusive and equitable energy systems across Europe.

One of the key insights from the ENPOWER project is the importance of citizen engagement in driving the energy transition. By providing citizens with tools, incentives, and platforms for active participation in energy markets, our analysis demonstrates how individuals can move from passive consumers to proactive energy citizens. Engagement strategies such as tailored communication, community-building activities, and simplified apps are essential to foster trust and participation.

The deliverable stresses how the integration of advanced technologies such as AI, blockchain, and digital twins can be critical for optimizing decentralized energy systems. These technologies enable real-time data analysis, secure peer-to-peer energy trading, and community-level energy optimization, showing that technological innovation is key to successfully managing distributed energy resources and fostering energy independence.

Different communities have unique energy needs, cultural contexts, and levels of technological readiness. ENPOWER's approach of tailoring both the technological and business frameworks to the specific characteristics of each pilot community highlights the importance of adaptability and customization. This ensures that energy solutions are relevant, efficient, and more likely to be adopted by local stakeholders. In this direction, the development of business models centred on shared ownership, local self-consumption, and value-stacking strategies shows that sustainable energy systems can also be economically viable. ENPOWER demonstrates that by creating P2P energy markets and enabling communities to trade energy directly, energy projects can generate both financial and non-financial benefits, making them attractive to a wider range of participants. In conclusion, the ENPOWER project lays a strong foundation for the future of energy in Europe. By fostering collaboration, enabling technological innovation, and placing citizens at the heart of energy transitions, ENPOWER supports the development of a decentralized energy ecosystem that is both sustainable and consumer focused. As the project's methodologies and frameworks are validated and replicated across different regions, it will contribute to building a more secure, democratic, and resilient energy future for all.

As the project progresses, the focus will now shift towards deeper technical development and the integration of feedback from initial implementations. Future deliverables will expand on this initial framework, detailing the specific technologies, processes, and operational models that will be employed. These will include comprehensive descriptions of the interaction between system components, the deployment strategies, and the use case scenarios that will be tested. Specifically Architectural description and technical requirements will be described in Deliverable D2.5.

5 References

[1] J. H. M. &. L. M. Torriti, "Demand response experience in Europe: Policies, programmes and implementation.," *Energy* , vol. 35, no. 4, pp. 1575-1583, 2010.

[2] M. B. Božičević Vrhovčak M, "Unlocking the Value of Aggregated Demand Response: A Survey of European Electricity Markets," *Energies,* vol. 16, no. 17, p. 6386, 2023.

[3] S. E. Europe, "https://smarten.eu/," February 2015. [Online]. Available: https://smarten.eu/wp-content/uploads/2015/02/SEDC-Enabling-Independent-Aggregation1.pdf. [Accessed 21 October 2024].

[4] S. &. N. G. Barbaro, "Energy communities in urban areas: Comparison of energy strategy and economic feasibility in Italy and Spain," *Land,* vol. 12, no. 7, p. 1282, 2023.

[5] M. K. Beatrice Petrovich, "Energy communities for companies: Executives' preferences for local and renewable energy procurement," *Renewable and Sustainable Energy Reviews,* vol. Volume 184, p. 113506, 2023,.

[6] D. &. K. M. Petrovich, "Environmental and Political Motivations for EnC," *Energy Policy,* vol. 67, no. 4, pp. 89-102, 2023.

[7] S. &. N. G. Barbaro, "Economic Incentives for EnC Participation," *Journal of Energy Economics* , vol. 45, no. 2, pp. 123-137, 2023.

[8] E. Commission, "Renewable Energy Communities in the EU," https://energy.ec.europa.eu/topics/markets-and-consumers/energy-communities_en, 2024.

[9] BD4NRG, "D2.5 - BD4NRG Reference Architecture First Version," [Online]. Available: https://www.bd4nrg.eu/sites/default/files/2023-06/BD4NRG%20Reference%20Architecture%20First%20Version%201.0.pdf.

[10] PlatONE, "D2.2 v1.0 Platone Platform requirements," [Online]. Available: https://www.platone-h2020.eu/data/deliverables/864300_M30_D2.2.pdf.

[11] OneNet, "D5.2 - OneNet Reference Architecture," [Online]. Available: https://www.onenet-project.eu//wp-content/uploads/2022/12/OneNet_D5.2_v1.0.pdf.

[12] BRIGHT, "D2.3 – DR Technologies and Tools," [Online]. Available: https://www.brightproject.eu/wp-content/uploads/2022/06/BRIGHT_D2.3_V1.0_ENG_.pdf.

[13] eDream, "D2.5 Requirement-Driven System Development V2," [Online]. Available: https://edream-h2020.eu/wp-content/uploads/2019/09/eDREAM.D2.5.CERTH_.WP2_.V1.0.COMPRESSED_compressed.pdf.