MASTERPIECE -
Multidisciplinary Approaches and Software Technologies for Engagement, Recruitment and Participation in Innovative Energy Communities in Europe

Deliverable 2.7

ARCHITECTURE DESIGN AND FUNCTIONAL BLUEPRINT

Title	Architecture design and functional blueprint
Document description	This document is the first one of a series of two with the same title. The document formalises and synthesises (technically and functionally) all envisaged operational blocks within the project's conceptual idea, based on the activities foreseen in T2.5 and considering the objectives. This primer version of this report (M9) supports the technical development and integration in WP3-4-5, to be then updated (M24) based on the feedback from pilots' evaluation in T5.6
Nature	Type and dissemination level: R-PU
Task	T2.5 + All WP2 learnings
Status	Final
WP	WP2
Lead Partner	UMU
Partners Involved	ODINS, EXP, UB, CERTH, ALWA, RDIUP, R2M, UEDAS, SEIN, BERC, ALEC, SUST, NGENIC, UPP
Date	30/09/2023

Revision history	Author	Delivery date	Summary of changes and comments
Version 01	Adelaida Parreño (UMU) and Alfonso Ramallo (UMU)	04/07/2023	ToC 1st version
Version 02	Adelaida Parreño (UMU) and Alfonso Ramallo (UMU)	18/07/2023	Updated ToC
Version 03	Adelaida Parreño (UMU)	31/07/2023	New section added
Version 04	Adelaida Parreño (UMU) Juan Sánchez (UMU)	08/08/2023	• Chapter 1, Section 2.2.4, Chapter 3, Chapter 4 and 5 - inputs • Chapter 5 -inputs
Version 05	Anna Maria Bagaini (UB) Juan Andrés (ODINS) Turkish, French & Italian pilot managers (UEDAS,	05/09/2023 09/09/2023 12/09/2023	• Chapter 2.1 - inputs • Chapter 2.2- inputs • Section 2.2.1 - inputs • Section 2.2.4 - inputs & Chapter 3 - inputs

	ALEC, SEIN, RDIUP and BERC) Charalampos Lazaridis (CERTH) + technology providers (UMU, ODINS, ALWA, R2M, EXP, RDIUP) Malek Anouti (EXP)		• Chapter 2.3 - inputs
Version 05	Adelaida Parreño (UMU) Alfonso Ramallo (UMU) Juan Sánchez (UMU)	15/09/2023	Chapter 3 - inputs
Version 06	Anna Maria Bagaini (UB) Juan Sánchez and Adelaida Parreño (UMU)	18/09/2023	• Section 2.1.4 - updates • Chapter 3 - updates
Version 07	Fabrizio Perrotta (R2M) Swedish pilot managers (SUST, NGENIC, UPP) Malek Anouti (EXP)	19-20/09/2023	• Chapter 3 - component table input • Section 2.2.1 – inputs • Chapter 2.3 – updates
Version 08	Fabrizio Perrotta (R2M) and Stefano Bianchi (ALWA)	22/09/2023	Revisions
Version 09	Adelaida Parreño, Juan Sánchez and Alfonso Ramallo (UMU)	27/09/2023	Final version. Ready for submission

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EXECUTIVE SUMMARY

The present deliverable is the first instance of a series of two and it formalises and synthesizes necessities and requirements on the so called the three dimensions of Energy Communities (ECs) regarding functional and technical aspects (i.e. regulatory and business, technological and social dimensions). The identified innovations are within the three dimensions.

- **Regulatory and business innovations** provide an overview of the legislation within ECs and the pilot cases of the project. It also examines the status of Business Models (BMs) and financial mechanism in these pilot cases, as well as the main identified barriers faced by these pilots.
- **Technological innovations** synthesise the hardware status of pilots cases and their respective pilot sites. Furthermore, it offers an overview of hardware needs for ECs. The section goes deeper into ICT communication protocols and standards regarding data privacy and security.
- **Social innovations** integrate social profiles aspects within ECs, along with needs and mechanisms for enrolment and engagement. In addition, it presents opportunities for innovation in management and governance within the ECs.

One each of these innovations. within its dimension, a comprehensive analysis has been done to identify the necessary functionalities that one may expect of a solution that would fulfil the objectives of this project. These findings have been separated in sections with a synthesised compilation of identified enabling technologies (i.e. methodologies and mechanisms) which can be useful in the dynamics of ECs.

The deliverable also includes an overview of preliminary components that would produce that enabling to provide a first conceptual approach. Additionally, it is presented the initial internal component template aimed to guide in the collection of more technical component detailed information. The template is within the three-dimensional concept.

Finally, a high-level architecture mock-up is provided offering a visual representation of the infrastructural starting point for the project.

1. Introduction

On the one hand, this deliverable identifies the innovations referred to each of the three dimensions of the ECs according to the MP framework (see previous deliverables): regulatory and economical, technological, and social. It also includes a synthesis of the outcomes obtained in the tasks of WP2 *'Energy communities requirements at national and EU levels for different stakeholders and shareholders'* and involves technologies (i.e., mechanisms, methodologies, tools, etc.) identified for these innovations. On the other hand, it provides (i) conceptual overview of the components, (ii) the presentation of the internal component template that will serve to obtain more technical detailed information on these components and (iii) a mock-up of the Masterpiece ICT platform architecture.

1.1. Relation to other tasks

This deliverable presents an overview synthesis of the different innovations and technologies/methods for said innovations within the three-dimensional concept. This concept corresponds to the triangle concept, resulting from activities carried out in tasks 2.1 *'Multilevel regulatory frameworks, administrative/operational barriers, market and financial requirements',* T2.2 *'Assessment of energy communities' maturity and aspirations in the pilot cases'*, and 2.5 *'Social innovations specifications and architectural blueprint'.* The three dimensions of the triangle concept (being three-dimensional concept) is briefly described in this deliverable, while in D2.1 it is described in more detail, explaining the triangle concept in all its aspects.

Additionally, this deliverable showcases the architectural mock-up of the Masterpiece ICT platform, which serves as a support for the future tools and components developed and modelled in WP3 *'Social and sustainable innovations modelling for energy communities' and* WP4 *'Digital platforms and tools for energy communities'*, which will be tested in the activities of WP5 *'Integration, demonstration & evaluation'.*

As said before, this deliverable, is the first version of the two deliverables under the title of *'Architecture design and functional blueprint'.* Deliverable 2.7 serves as the starting point for deliverable D4.1 *'Requirements of the digital platform, conceptual design and definition of the tools for flexibility'* and therefore for the tasks of WP4. The update to this D2.7 will be D2.8 *'Architecture design and functional blueprint - update'.*

1.2. Structure of the document

The document is divided into five main sections. Chapter 1 is the introduction of the document. Chapter 2 is dedicated to the requirements of the innovations pertinent to the three-dimensional concept. This section briefly addresses the implications of the three dimensions that permeate throughout the deliverable, specifically in the three sections of Chapter 2: Section 2.1 "Regulatory and Business Innovations", Section 2.2 "Technological Innovations", and Section 2.3 "Social Innovations". The objective here is to summarise and provide a conceptual overview of the innovations within these dimensions. Therefore, an overall perspective is provided on the regulatory framework and business models; the technological aspects such as the status of the pilots and hardware and security features; and the various mechanisms, social profiles, and management and governance opportunities involved in social innovations. Each subsection concludes with the technologies identified for these respective innovations' sections.

Chapter 3 presents foundational information, from a conceptual standpoint, of the components to be developed and used within the project. This will provide an overview of the functionality, preliminary inputs, and outputs of these components. This sets the stage for Chapter 4, where the internal component template is introduced for the first time. This template encapsulates the information to be requested from the components. Chapter 5 provides the architectural mock-up of the Masterpiece ICT platform. Finally, the deliverable ends with Chapter 6 for the conclusions.

2. REQUIREMENTS FOR INNOVATIONS

The three-dimensional concept is first described in D2.1. The visual representation is in the following figure with the representation of the EC triangle.

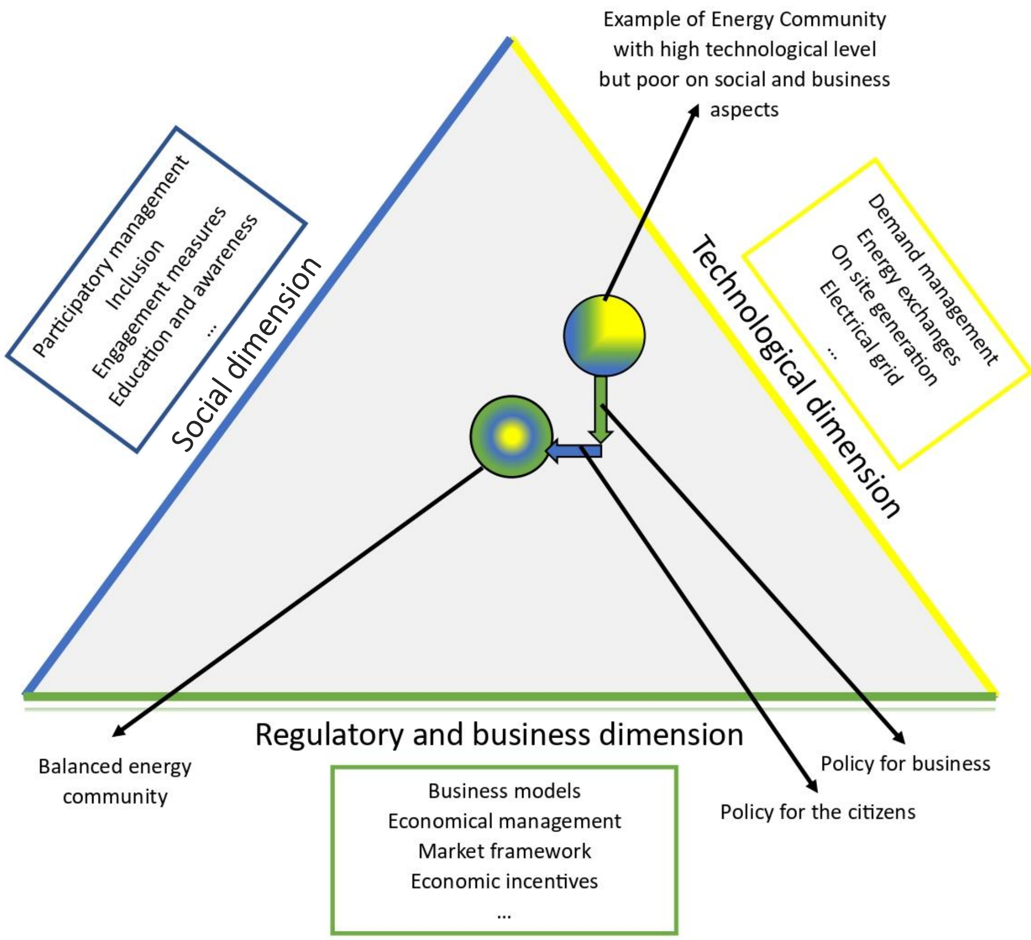

Figure 1: EC triangle concept

The triangle concept pertains to the combined configuration of the three dimensions: business and regulatory, technological, and social, which have been identified within WP2 as pivotal in energy communities. Each of these dimensions represent a side of the triangle and they all are influenced by policies. This framework has been defined to facilitate diverse activities regarding ECs that will be carried out throughout the project. Throughout the present deliverable, when it is need, the concept will be referred to as the three-dimensional concept.

This chapter is concerned with the requirements for innovations present in each of these three dimensions. Additionally, within each of these three dimensions, an overview will be presented to synthesize the knowledge acquired from the diverse activities conducted up to the present report, along with preliminary technologies identified for these innovations.

2.1. Regulatory and business innovations

The economical dimension entails how an EC operates within the market context describing its long-term economic sustainability. It aims to explain how an EC can generate, deliver, and capture value, considering different aspects, starting from the EC value proposition, type and role of stakeholder participating in the EC development and operations, key resources, setup financing mechanism and revenue streams. There is not a unique archetype of business model that can explain how ECs work, generate, and deliver values. This can vary among initiatives and experiences. According to Gjorgievski et al. In reference [1] this can depend on five factors such as purpose, performed activities, legal form, connection with the territory and to the grid seen in the following table.

Table 1: Existing categories of ECs found in the literature

Factors	Categorisation
Purpose	Single-purpose, multi-purpose
Performed activities	Energy management, energy generation, self-consumption, energy retail, flexibility services, e-mobility
Legal form	Energy cooperatives, limited partnerships, community trusts and foundations, housing associations, non-profit customer-owned enterprises, public-private partnerships, public utility company
Connection with the territory	Place-based, non-place based
Grid connection	On-grid, off-grid, hybrid

Those aspects are influenced by regulatory and policy frameworks set at the EU and national levels. Regulation and policy frameworks can play either a facilitating or hindering role in ECs' development and operations by driving the energy transition path and influencing all decisions concerning the energy market, including ECs. The presence of regulations clearly defining the EC characteristics, duties and responsibilities towards its members, grid operators and other energy market actors is a pre-requisite to allow a proper EC setup and operations while avoiding the rise of energy grid congestion, unbalancing and the increase of grid management costs. From the side of supporting policies, many instruments such as subsidies, incentives and grants have been put in place by public authorities to boost EC development. For instance, the setup of supportive tariffs, i.e., feed-in tariffs, allows small-scale energy producers to sell the energy they deliver to the grid at an above-market price. Small prosumers and ECs get advantages from this policy, through which they could cover the expenses related to installing and maintaining power generation plants, energy storage systems, and local smart grids. The EC promotion through a reduction of energy network levies can also generate advantages for community members. The technological and social dimensions of an EC are also affected by regulations and policy frameworks. For instance, digitalization strategies influence EC management and services by setting rules on data protection, data usability and privacy. Regulatory and policy frameworks can drive people's behaviours by raising public awareness, encouraging specific behaviours through incentives and taxes, and protecting rights of energy consumers and prosumers. In terms of inclusion, special attention is given to low-income citizens in regulatory and policy frameworks among EU Member States. This attention affects ECs' social aims and purpose along with people engagement.

2.1.1. Overview of policy frameworks at the EU and national levels

At the EU scale, there are two main directives that directly regulate and define ECs. First, the recast on renewable energy - Directive (EU) 2018/2001 (RED II) [2] mentioned EC as a Renewable Energy Community (REC). The Internal Market for Electricity - Directive (EU) 2019/942 (IEMD) [3] gives another definition of EC as a Citizen Energy Community (CEC). Both directives explicitly promote the engagement of consumers in the energy transition considering them "at the heart of the energy markets” [4]. In detail, RED II defines the REC as a legal entity that *“is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects owned and developed by that community”* and *“whose primary purpose is to provide environmental, economic or social community benefits for its members or the local areas where it operates rather than financial profits”*. IEMD defines the CEC as a legal entity that *“may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders”* [5].

There are some differences between the CEC and REC definitions. CECs focus on electricity and do not have a technology-specific focus, while RECs engage specifically in activities related to renewables. Furthermore, RECs are rooted in place, while no such requirements exist for CECs. In governance terms, RECs also represent a subset of CECs because they are generally stricter in terms of eligibility, effective control at the local level and democratic governance [6]. Specifically, REC is autonomous; however, CEC is not independent and only sets restriction rules for large energy companies, so they cannot interfere in the decision-making of EC. Key aspects and key differences between REC and CEC are summarized in the following table [7].

Table 2: Comparison of key aspects of Renewable Energy Communities (REC) and Citizens Energy Communities (CEC).

Main features	Renewable Energy Community (REC) - Directive (EU) 2018/2001 (RED II)	Citizen Energy Community (CEC) - Directive (EU) 2019/942
Membership Status	Open and voluntary involvement; the shareholders or members are individuals, micro, small or medium-sized enterprises (SMEs) or local authorities	Open and voluntary involvement; members or shareholders are individuals, local authorities, including municipalities, or small enterprises
Autonomy	Autonomous	Not Autonomous, (restricted decision-making of large energy companies in EC)
Management of EC	Efficiently managed by shareholders or members that reside close to the renewable energy projects owned and constructed by the REC	Efficiently managed by members or shareholders; the decision-making abilities should be limited to those members that are not connected with large-scale commercial activity
Geographical limitation	Reside close to REC	No limitation

Primary purpose	To deliver environmental, economic, or social benefits to EC's members or shareholders Instead of focusing on financial gains	To deliver environmental, economic, or social benefits to EC's members or shareholders Instead of focusing on financial gains
Activities	Generation, distribution, consumption, energy storage, aggregation, energy supply and distributing energy-related services	Generation, distribution, energy supply, consumption, energy sharing, aggregation, energy storage, energy-efficiency services and EV charging-services

The transposition of the RED II and the IEMD EU directives into national laws is necessary to define national policies that aim to support and boost citizen-centred initiatives and strengthen citizens' rights within the energy market.

According to the REScoop transposition tracker [8], the transposition situation of EU Member States can be categorised into four different categories, namely 'Bad transposition', 'Substantial deficiencies', 'Average progress', and 'Good practice'. Next figure illustrates the transposition situation of the EU Member States. Four Member States are in the bad transposition category, 10 Member States are in the substantial deficiencies, seven Member States are in average progress of transposition, and six Member States are in good practice of transposition.

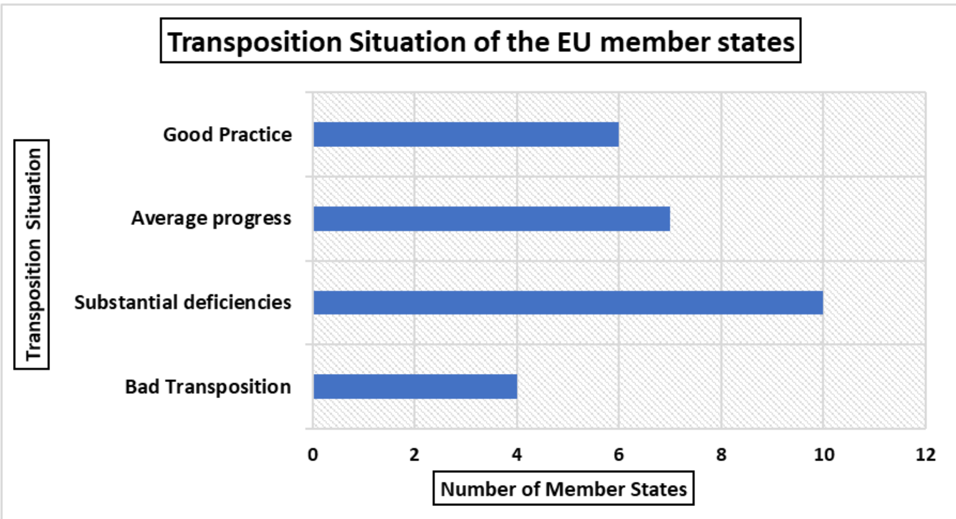

Figure 2: Transposition situation of the EU Member States

In order to gather specific information regarding national policy frameworks on ECs in the four pilot countries involved in the Masterpiece project, a survey has been designed and delivered to pilot case managers. Through the survey, we asked about the national transposition level of EC directives, i.e., RED II and IEMD directives, information regarding EC national and sub-national laws and regulations for energy sharing, the presence of public incentives supporting ECs and fiscal norms defining network charges, tariffs and levies to ECs connected to the grid. Results are shown in the next figure.

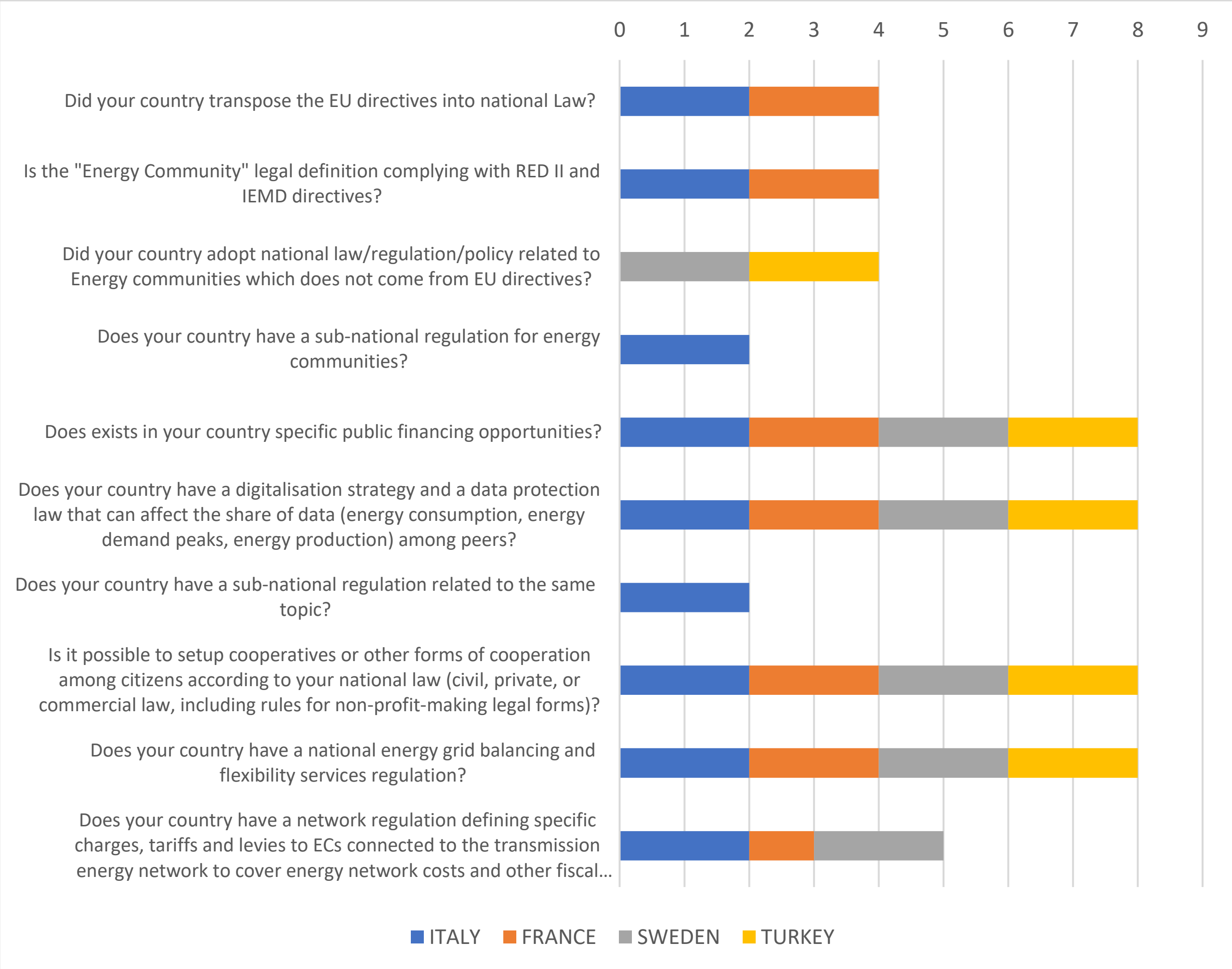

Figure 3: Pilot cases managers' answer

Looking at pilot case managers' answers, 2 countries, Italy and France, have fully adopted in their national laws the two mentioned EU Directives, taking over the same definitions, terms and criteria as the EU directives for both REC and CEC. In Sweden, the government has not formally finalized the energy community's transposition regulations. Sweden does not require new legislation to regulate ECs. Turkey's EU directives transposition situation cannot be evaluated, as Turkey is not part of the EU. Specifically, Turkish energy legislation does not directly address RED II and IEMD definitions and regulations [9]. However, community-driven collective energy generation and consumption is allowed, but it is limited to natural or legal persons or cooperatives in the same tariff group system and using the same connection point, or those whose electrical energy consumption can be monitored with a single common meter [10]. Furthermore, in all countries, citizens can decide to cooperate and participate in the energy market by creating a new legal entity that is disciplined by national law (civil, private and or commercial law).

Regarding EC sub-national laws and regulations, only Italy performs it, since any region can promote specific legislation on strategic topics that go beyond national regulations.

All countries provide public financial opportunities in terms of supporting tariffs for selling the exceed energy (i.e., Feed-in-Tariff and Feed-in-Premium mechanisms in France and Turkey), electricity sharing incentives along with a deduction of grid costs charges in Italy, participatory bonus in calls for tenders in France, tax relief and reduced real estate tax for RES production in Sweden. All countries also have specific digitalisation strategies and data protection laws that can affect ECs operations.

All countries have national regulations to manage the electricity market and the electricity network operation, considering balancing issues and the opportunity to provide flexibility services by aggregated citizens and ECs. In Italy and Sweden, EC members are requested to pay network tariffs to cover the network costs.

2.1.2. Overview of EC BMs models and financing mechanisms in Masterpiece pilots

According to our analyses (see Deliverable 2.1) the EC can be seen as an innovative sustainable business model since it aims to generate environmental benefits and increase citizens' empowerment [11]. Furthermore, EC does not only redefine the value proposition of its BM but it also sets a new organizational structure and new activities in the energy sector [11], [12]. The EC organizational structure and the decision-making process through which the EC members participate in the energy market can be considered the two most prominent innovations of the EC BM [12].

In order to understand Masterpiece pilots' BMs, we designed and delivered a survey to pilots' managers asking them about their ECs aim, promoter, legal form, assets ownership and control, organizational structure, decision-making and financing sources. The answers presented in the following table help in understanding the setup status of the ECs of the pilots, and what they plan to become in the following years with the support of Masterpiece partners. Since these ECs are in the preparatory and setting up phase, pilots' managers could only provide a prevision of what the EC will be under a BM perspective. The Turkey EC is the most advanced since it has already decided the organization structure, legal form and value-sharing model. The others are still deciding on many aspects concerning the questions provided to them.

Table 3: Overview of the answer for the understanding of the setup of the ECs

	ITALY	FRANCE	SWEDEN	TURKEY
What is the near legal definition in the EU regulatory* framework for your EC? **(Provided by the Clean Energy package in 2019)*	Renewable Energy Communities	Renewable Energy Communities	Renewable Energy Communities	Renewable Energy Communities
Under what legal form/entity is the EC currently/(or will be) ?	Not yet established	Not yet established. Mainly non-profit enterprise	Non-profits association	Non-profits association
Who is/was the promoter?	Public Authority	NA	NA	Private association

Who does own the assets (energy microgrid, generation assets (e.g. Solar, wind, hydro), energy storage systems, smart metering and devices for controlling the energy flow)?	Energy microgrid: AEC Berchidda; PV systems and Wind systems: private/public building owners, local enterprises; Smart metering/devices : Berchidda municipality; Energy storage system: Berchidda municipality	Power plants: Library, Molière centre (school), "Léo Lagrange" (cultural centre)	NA	EC members (equally)
How are members organized /going to be organized in the EC?	Governance under definition	Governance under definition	NA	NA
How are decisions being/going to be made in the EC?	Voting rights and meetings	Voting rights and meetings	Voting rights. Decisions are made up of majority votes. Assembly and meetings	Mail groups, social media (WhatsApp group), annual meetings minimum 2 times, 1 general assembly every year. Voting rights (“one member-one vote”)
Do all stakeholders participating in some way in the energy community have the same rights and relevance within the decision-making process?	All members will have the same right to vote. Member voting weight under investigation for its potential implications	NA	NA	All members have the same voting rights
How is/going to be financed the EC?	A mix of public/private funding	EU and national grants	NA	Equity owned by members and national funds
How are profits and risks shared among members?	Under the cooperative law profit and risks are shared equally among members	Not yet defined	NA	Under the cooperative law profit and risks are shared equally among members

ECs under development in the four pilot cases are in line with the Renewable Energy Communities definition since they rely on RES self-production and consumption. In all cases, power generation is located close to EC members. Members can play both the role of consumers and prosumers since the energy generated is shared among the members to maximise and optimize self-consumption. In the Italian and French pilot cases, the EC legal form is not defined yet. However, according to the Italian and French national laws, REC's primary purpose is to generate environmental, economic or social benefits for its members rather than financial profits. In Sweden and Turkey pilot cases, the ECs will be a non-profit association where the main aim is to produce and share energy among the community members. According to pilots' managers, the Italian EC is promoted by a public authority (the Municipality of Berchidda), while the Turkey one is mostly promoted by a private association working in the field of climate change and energy efficiency (Troya Environmental Association). The assets (energy microgrids, power plants, energy storage systems, and smart metering) are owned by the community members in all pilot cases. In detail, in the Italian pilot case, the energy microgrid is owned and controlled by the public utility, power plants are owned by private and public building owners and local enterprises on which the PV panels and wind turbines are installed, smart meters installed in the EC members' homes are owned by the Municipality as well as the energy storage system.

In the French pilot case, the power plants are owned by public stakeholders, namely the public library, a school, and a cultural centre. In the Sweden pilot cases, the ownership is not defined yet. In the Turkey pilot case, the ownership of the assets is equally shared among EC members as required by the law for cooperatives. Regarding the EC organization structure, the Italian, French and Sweden pilots have still to decide how to build it. However, in all cases, there will be full participation and involvement of EC members in the EC decision-making process through voting rights, assembly, meetings and social platforms where members can interact constantly.

In Italy and Turkey, EC members will have the same right to vote, even if the Italian pilot is considering setting up different weights in the voting scheme depending on the value-sharing approach they will decide. Value-sharing refers to any model used for distributing the economic value generated by EC operations to EC members [13]. In general, the sharing-value model should be designed to incentivize members to act in a way that generates trust, a sense of community and benefits for all members, reducing dissatisfaction and preventing members from leaving.

The EC financing mechanisms strongly differ among pilot cases. With financial mechanisms, we intend all processes and instruments used to raise capital and finance EC initiatives, as well as forms of revenue, for example through the selling of EC shares. Those can be provided by public and private bodies and can target the whole EC or the energy assets (i.e., microgrids, generation plants, energy storage systems, smart metering, etc.). Private financing mechanisms include equity or debt financing, energy performance contracting and crowdfunding. Public financing mechanisms include grants, incentives, public bonds, etc. (see Deliverable 2.1 for more information). In Italy, the EC will be funded by a mix of public and private funding. In Turkey, the EC is fully funded by members through equity and opt-in fees. In France, the EC will be mostly funded through European and national grants. Profits and risks are equally shared among EC members in the Turkey pilot case. The Italian one is still under discussion. The profits will be shared according to the legal form and the sharing-value model set up to govern the EC. The French and Sweden pilot cases are still deciding in this regard.

2.1.3. Overview of Masterpiece pilots' barriers hindering ECs

In deliverable D2.1 we reported and analysed the most recurring barriers hindering EC setup and operations that emerged in the literature. Sorrell et al [14] define a barrier in the energy sector as *"a mechanism that inhibits a decision or behaviour that appears to be both energy efficient and economically efficient"*. We group barriers identified in our analysis into four main categories: 1. economic, 2. institutional, 3. technological and 4. behavioural, including social, cultural and educational [15]. Economic barriers refer to difficulties in accessing credit, insufficient and unstable available funding, high risk for investors and financial institutions [16], [17], [18]. Institutional barriers are related to political obstruction, conflicting guidelines, and lack of policy coordination [19], [20], [21]. Technological barriers refer to the limited availability and spread of technologies (e.g., smart meters, energy storage and smart devices), inefficient and old energy infrastructures [1], data protection and data security [22]. Behavioural barriers refer to low awareness, lack of information or behavioural anomalies in processing information, lack of trust, customer attitude, lifestyle, etc.[18], [23], [24].

According to our analysis of the literature, we asked pilots' managers to rank the 5 categories of barriers from 1 to 10, where 1 refers to a low affecting level and 10 to a high level. Since ECs in the 4 cases are still in the preparation and setting up phase, we only asked them about barriers affecting the setting up of ECs in their countries according to their experience (following figure). Sweden's pilot did not provide any answer.

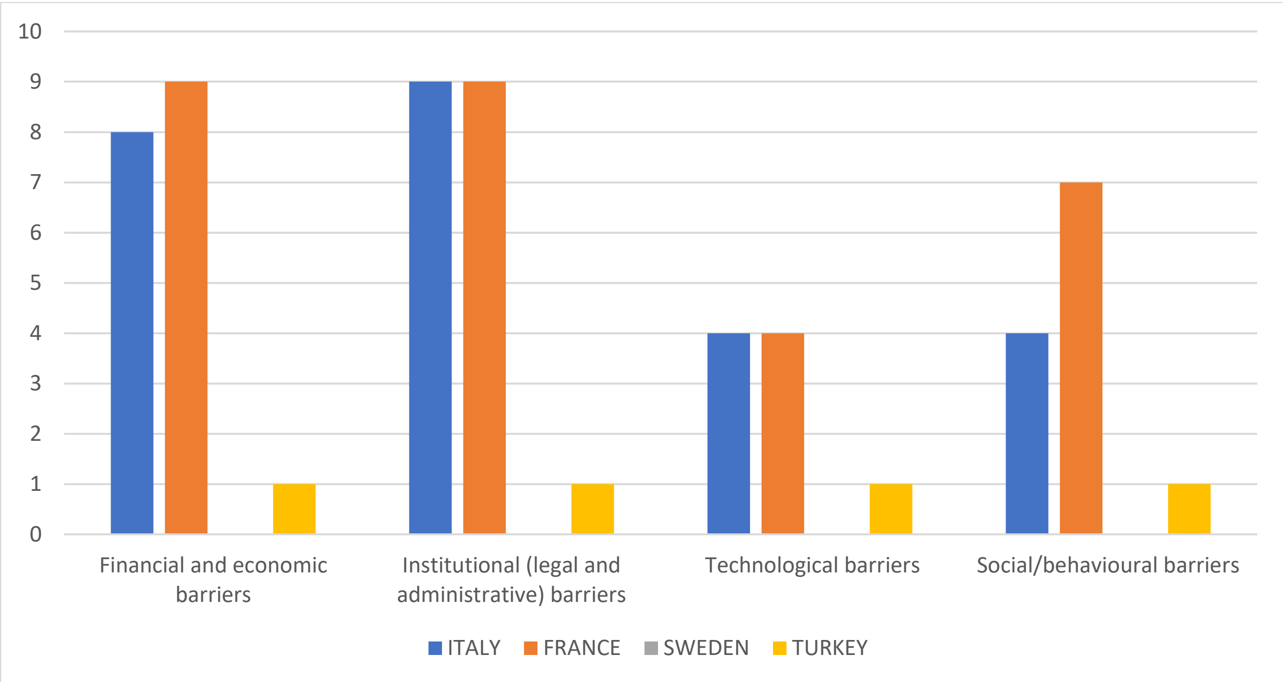

Figure 4: EC setup barriers ranking by pilot managers' experience in the pilot cases

According to pilots' managers, the most affecting barriers concern the category of "institutional (legal and administrative) barriers", followed by the category "Financial and economic barriers", confirming what was discovered in the literature. Social and behavioural barriers are considered highly affecting in France. This may be related to the country's energy market that mostly relies on centralised nuclear energy that disincentivises decentralised and distributed RES production and consumption. Technological barriers are considered less effective since access to many technologies (e.g., smart meters, PV panels, storage, etc.) has become easier in the last decade. The Turkey pilot did not encounter many barriers in the EC setup.

2.1.4. Preliminary technologies identified for the innovations

The regulatory and business dimension strongly rely on technologies (energy optimization and management systems, energy storage, EV chargers, smart grid, power plants, etc.) and users participation. Those two can entails both physical and digital environments. For instance, the interaction of EC members can be physical, through meetings and assemblies, virtual or both. The interaction between technologies, users' participation and the regulatory framework affect decisions in terms of BM.

Since there isn't a unique ECs BM that fits all situations, it is necessary to support pilots to design a suitable and successful BM. To this purpose Masterpiece will provide an innovative BM framework that will support pilots in defining a tailor-made BM, considering financing mechanisms, sharing-value models, organization structures, and revenue streams, etc. This simulation tool can be used to compare BMs and analyse impacts on the ECs. This tool is also crucial to define the financial plan and the participatory plan to make the EC profitable over time and plan activities needed to engage participants. The tool is based on information collected through desk research and literature review. Users can change according to the maturity of the EC and their role. In an EC set-up phase, the users will be the stakeholders interested in the EC development. Those will use it to design a tailor-made and suitable energy community business model. In the operating phase, users are the EC members who intend to enlarge the services and profitability of the EC.

When P2P energy trading BM is taken into consideration, the set-up of a proper platform to manage and control the exchange of energy is pivotal. In this case, users get access to a private trading platform in the form of an app, which monitors the energy market among peers. A transparent and secure register of each member using blockchain is needed to assure security, control and privacy.

Considering the relevance of market mechanisms (e.g., incentives, EPC schemes, energy network fee deduction, crowdfunding, net-metering or pay-as-you-bid mechanisms, local carbon/energy efficiency credits, etc.) in setting profitable and suitable BMs, a tool listing market mechanisms available at the local scale is provided through Masterpiece in the form of a digital tool. The decision-supporting tool will allow users to make informed decisions on EC BMs thanks to the simulation of mid-long-term remuneration of each market mechanism. The tool is based on information collected through desk research and literature review. It will be open to all stakeholders interested in setting up an EC or increasing its profitability. Data are provided by the users to simulate the remuneration of market instruments. The privacy of the users will be assured as well as the results of their simulation.

2.2. Technological innovations

The technological dimension of energy communities extends beyond the mere employment of physical devices. It encompasses the adoption of pivotal technologies and digital tools essential to their functionality. These components, including the Internet of Things (IoT), intelligent solutions, digital platforms, and management and monitoring tools, play a pivotal role in advancing the technological aspects of ECs.

Within the following subsections, it is explored various facets that contribute to the enhancement of ECs' functionality, efficiency, and integration. From assessing the current state of the project pilots to identifying hardware requisites and delving into ICT communication protocols and standards for ECs. Additionally, the last subsection offers a comprehensive overview of how technology is driving innovation within the ECs landscape of the project.

2.2.1. Overview of the pilot's situation

This section details a general description of the current situation of the Masterpiece pilots. In this sense, in each subsection a brief description and the hardware elements/challenges per pilot scenario are detailed.

Table 4: Summary of the pilots of the project

Pilot case	Pilot partner acronym	Pilot site
SWEDEN	NGENIC	BRF Väppeby Backe
		BRF Venus
		Austerland
	UPP	Dansmästaren
TURKEY	UEDAS	Çanakkale
FRANCE	ALEC	Solévent
	SEIN and RDIUP	PART'Ener and Les Mureaux
ITALY	BERC	Municipality of Berchidda

Each pilot site is organized within the section under the following title format subsection:

[Pilot Case Country] – [Pilot Partner Name] – [Pilot Site Name]

2.2.1.1. Sweden – Ngenic – BRF Väppeby Backe

Introduction:

The housing association composes of 40 apartments in four shared buildings where they are currently focusing on energy efficiency. Ngenic is implementing individual metering per apartment and have reduced the grid connections to four. In half of the apartments there are temperature sensors that control the central heating water-based heating that comes from ground source heat pumps. Furthermore, they have shared EV charging and PV production.

They want to explore possible energy sharing through DC network or possible virtual energy sharing between the four DSO grid connections along with batteries to store PV energy and optimize power peaks. There is a high need to have a better understanding of the EV charging and PV production and the overall total energy usage. Currently, the majority of the 40 tenants does not engage in the community only the board.

Hardware elements:

- 5 DSO grid owned electricity meters one for the heat control system and the rest for apartments.
- 40 housing association owned apartment electricity meters.
- 60kW ground source heat pumps with Ngenic tune Highrise[1] control 10kW electricity heater.
- 20 Inside temperature sensors that also have humidity sensing.
- PV panels on one building for electricity production connected to the heat control system and providing the heat pumps with electricity (not the apartment).
- Solar heat production.
- 40 EV chargers. There are only 5 EVs that charge in the night.

Hardware challenges:

Installing the DC network between buildings is on the way, however, it has not been ordered and can be challenging to manage. The addition of batteries will take time and control logic, together with the financial challenge.

2.2.1.2. Sweden – Ngenic – BRF Venus

Introduction:

The housing association composes of 800 apartments in one building with individual electricity metering per apartment and perform power peak management and energy sharing between 11 grid points. They are planning to add PV's and extend EV charging. The goal is to be able to engage more tenants very few are today engaged in the energy system.

Hardware elements:

- 11 grid owned electricity meters, 7 provides power to the apartments and the other four to garage and common facilities.
- +20 EV chargers operated and billed for usage separately can be part of pilot.

Hardware challenges:

Adding PV is a challenge since it is costly and needs to be divided between the DSO meters.

2.2.1.3. Sweden – Ngenic – Austerland

Introduction:

The housing association composes of single villa that cooperates with a collective water solution (among other things). They are planning to install 1MW PV park with some 100 members/customers.

They have created a separate non-profit for a CEC association (ekonomisk förening) to co-own the PV park. The idea is to be able to perform virtual energy sharing from the PV park. Through this new

[1] https://ngenic.se/en/tune-highrise/

association, they are trying to force the DSO to change their stance on policies. The goal is to be able to engage more tenants very few are today engaged in the energy system.

Hardware elements:

- All villas have only DSO meters. Some individuals have PV solar, EV charging battery etc.
- Some but not all will have their own Ngenic systems.

Hardware challenges:

All villas are individual systems and therefore a challenge to integrate.

Data from DSO will only generate 1h of data.

2.2.1.4. Sweden – Uppsala – Dansmästaren

Introduction:

The facility is a so called multihub consisting of municipality owned student housing apartments, a parking garage with EV-charging and a private convenience store. On the roof of the facility there are two PV sites owned by Uppsala municipality. The multihub is located close to the city centre, adjacent to a newly developed urban area with a focus on climate positivity. Uppsala municipality's object with this pilot site is firstly to establish an EC community where energy can flow freely between PV's, residents, mobility, and partners, and in the long run to connect this pilot site with adjacent buildings to further the EC.

Hardware elements:

- PVs on the rooftop (municipality).
- Battery in the basement (municipality).
- Full installation of meters that measure electricity consumption from the building (lightning, EV charging, elevators, etc.) Also, full metering of thermal energy.

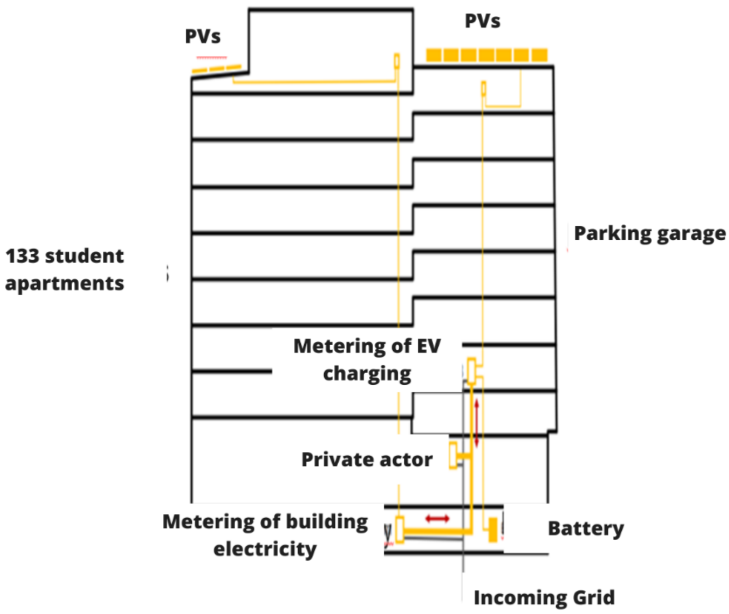

Figure 5: Hardware elements in Uppsala pilot site

Hardware challenges:

Hardware challenges include choosing and installing extra meters for a more detailed dataset. Individual metering of the apartments must clear GDPR requirements.

2.2.1.5. Turkey – UEDAS – Çanakkale

Introduction:

UEDAS will install solar power plant on the roof of public housing of UEDAS Çanakkale Operation and Administration. Public housing consists of two interconnected four-story buildings, constructed in the 1980s, stand closely united. These two buildings share a unique connection and together comprise a complex that houses a total of 16 individual apartments. With a combined total of eight floors between them, these buildings offer a sense of community and shared living within their distinct architectural framework. UEDAS will install 16 pcs 3 kW PV power plant on the roofs of buildings. Other than that, its' car parking spot roof is also alternative area that is feasibility studies done to install solar power plants. Moreover, 16 pcs residential customers are selected to replace their meters with Nb-IoT type smart meters. Within the scope of the project, data of energy flow will be monitored and saved.

Hardware elements:

- Solar Panels.
- Nb-IoT meters.
- Inverters.

Hardware challenges:

Hardware challenges associated with the installation of solar panels include designing and implementing effective mounting and support structures that can withstand various weather conditions and loads, optimizing the angle and orientation of panels for maximum energy capture, integrating the panels seamlessly with existing infrastructure, ensuring proper wiring and electrical connections, and addressing potential shading issues that can reduce overall system efficiency. Additionally, safety considerations for installers and maintenance personnel are important, as well as meeting local building codes and regulations.

Solar inverters in residential buildings encounter various hardware challenges that require careful consideration. One significant issue is managing the temperature generated during operation to prevent overheating and maintain optimal performance and longevity. Another challenge involves designing compact inverters that fit within limited residential spaces while still delivering the required capacity. Reliability and durability are paramount, given the diverse environmental conditions these inverters face, including temperature fluctuations and potential exposure to the elements. Addressing noise, vibration, safety features, and grid synchronization further emphasizes the intricate nature of designing solar inverters for optimal performance in residential settings.

Installing Narrowband Internet of Things (NB-IoT) smart meters presents certain hardware challenges. Some of these challenges include designing the meter hardware to be compact and easy to install in a variety of environments, ensuring the devices are tamper-resistant and secure against unauthorized access, integrating the necessary communication modules and antennas for NB-IoT connectivity, optimizing power consumption to prolong battery life or reduce energy usage, and addressing potential interference or signal quality issues that might arise. Additionally, the smart meter hardware needs to be compatible with existing metering infrastructure and compliant with relevant industry standards and regulations.

2.2.1.6. France – ALEC – Solévent

Introduction:

Solévent was created in November 2018, 171 people are now involved in this energy community. **Citizens, cities, companies, and associations** can take part in the capital. For the moment, they are only working on photovoltaic solar energy.

293 MWh are produced each year, all of which **is reinjected into the grid**. Total investment is €275k.

Solévent is an SAS (simplified joint stock company) with variable capital and **cooperative operations**. Any individual can apply to become a shareholder, and legal entities can become shareholders in the company.

The Bordeaux City Council has voted to acquire a stake in Solévent. Solévent is working the department of Gironde on some projects. A part-time employee has been working for the EC since November 2020. This person is responsible for project development, community organisation and communication.

Today, in the Gironde department, four schools have photovoltaic solar panels on their roofs thanks to the EC. The output of the solar panels is visible in real time for each building via an application (these data will also soon be freely available on the CE website). This application (Sunny Portal) is included with the purchase of the inverter (SMA)

Table 5: Summary of installations in Solévent's pilot

Name of installation	Power installed (kWc)	Investment (€)	Foreseen production (kWh/year)	Comments
School Marcel Sembat - Bègles	36	40 000	45 000	40 000 kWh/year were foreseen)
School Betey - Andernos	84	90 000	96 000	94 000 kWh have already been produced in 10 months
School Gambetta - Bègles	33	47 000	36 000	26 000 kWh have already been produced in 7 months
School Centre - Le Bouscat	100	90 000	115 000	

There are seen as a future projects 6 other installations were planned for 2023 on schools' roofs, but the structure studies showed that the buildings need reinforcement, so the projects are delayed.

Solévent will install solar panels on the roofs of 4 new schools in Bordeaux by the end 2024 – beginning 2025. Stéhélin, Bordeaux: 200 to 256 panels

- Matteoti, Bordeaux: 72 to 96 panels.
- Nuyens, Bordeaux: 72 to 96 panels.
- Benauge, Bordeaux: 200 à 530 panels (not sure about the structure).

Additionally, Solévent will work with a social housing organisation. Solévent will invest on an installation on the roof of Plantille Residence (117 apartments – 200kWp - 400 solar panels) and will run workshops about energy savings for the social tenants. Unfortunately, they couldn't manage to agree on a Self-consumption business model, so the electricity will be sold/ fed back into the grid.

Hardware elements:

- Solar Panels made in France or Europe
- No storage
- Smart meters "linky"
- Inverters

Hardware challenges:

As explained, the 2023 projects have been delayed because the roof structure studies demonstrated that the existing building couldn't support solar panels as they are. → The structural study is not yet done for Les Plantilles. It is foreseen next year.

As Solévent's specificity is to install solar panels, they must get particularly precautious about the security and the access of the technical rooms. The temperature of the inverters will become more and more problematic.

2.2.1.7. France – SeinergyLAB and RDIUP – PART'Ener and Les Mureaux

Introduction:

SEINERGY LAB is working on a collective self-consumption experimentation and is developing two pilots (ongoing) in the regional territory (Poissy and Magnanville). Each pilot corresponds to a shared photovoltaic power plant of 100 kWc and building participants (loads).

The objective of this pilot is to give as many people as possible access to local renewable energy. The PART'Ener project proposes to develop a shared power plant (land, economies of scale, project management, operation, etc.) to which all the players in the territory can join. Each partner consumes the share of the energy produced that corresponds to its financial participation in the project.

Another pilot in Les Mureaux will be created based on the lessons learnt from PART'Ener and by using the tools of engagement and co-design developed in Masterpiece. In the same direction, in Les Mureaux, shared productions of about 100 kWc and multiple building participants will be engaged to create a REC. new type of participant will be considered also a storage system will be studied and sized in this pilot.

Hardware elements:

- Solar Panels (110 kWp)
- Smart meters (Linky)
- Inverters (Enedis)

Hardware challenges:

Beyond PART'Ener, in Les Mureaux, we intend to study the implementation of energy storage systems to improve the performance of the EC and provide new services in the post-project. At this stage, it is recommended to assess two options:

- Size and integrate a small storage capacity (home battery or installation PV battery)
- And/or include the charging stations in les Mureaux EC.

As challenges, the measurements and deployment of smart meters if they are not embedded in these systems of storage or charging, the implement of a dynamic load system or the installation of a module to control the storage battery.

2.2.1.8. Italy – Berchidda – Municipality of Berchidda

Introduction:

The Municipality of Berchidda is one of the very few municipalities in Italy to own its own electricity grid (80%, soon to become 100%). On its municipal territory there are 106 private houses with domestic photovoltaic systems, and 5 photovoltaic systems (20 kWp on average) installed on municipal buildings (gymnasium, school).

The municipality wants to create an energy community and to do this, according to Italian regulations, it needs to have photovoltaic installations on its territory built after 2020. For this reason, it has identified an area in its industrial zone that lends itself to the installation of a large PV plant (pre-assessments are being made, but it should be no less than 1 MW).

In the meantime, the municipality has purchased 1,500 smart meters that will be installed in as many private buildings, ready for the energy community once it is legally and technically established.

Hardware elements:

- Solar Panels
- Smart meters mono phase
- Smart meters triphase
- Inverters

The new telemanagement system, thanks to the installation of these second-generation smart meters, all of which will be installed by November 2023, will make it possible to improve the overall quality of the electricity service by increasing the data available for more efficient management of the electricity grid: for example, it will be possible to monitor the voltage value in more detail and detect faults more quickly, thus reducing the duration of interruptions. In addition, the following data will be available on the smart meter display:

- check how much electricity has been consumed, broken down into different time slots;
- examine the daily consumption trend in detail, thanks to the measurement data per quarter-hour;
- know the actual power consumed at any given time.

Hardware challenges:

The hardware challenges that may arise relate primarily to the installation of the PV modules on the Berchidda industrial area. As this is a large PV plant, the design and implementation of mounting and support structures will have to be adapted to the context: strong winds and high temperatures. This is so that the plant can give the best production guarantees, taking into account the optimal orientation, calculation of possible shading, guarantees of adequate wiring and electrical connections, also in view of the installation of smart meters on private buildings that should allow the actual realisation of the REC.

Great attention will have to be paid to the positioning of the inverters of such a system: the problem is not so much space, but a location with adequate protection from atmospheric events that at the same time allows the necessary ventilation.

O&M and the entire package of safety regulations for both the installers of the 1 MW plant and the maintenance personnel will also have to be taken into account. These are the same personnel who manage the maintenance of Berchidda's electricity grid and who will also manage any problems that may arise with the smart meters.

Regarding the installation of the smart meters and hardware challenges: prior to their installation, their compatibility with the existing metering infrastructure and their compliance with industry regulations was verified, so that no problems would arise once they are operational.

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2.2.2. Overview of hardware necessities for ECs

Energy communities are focus on the use of energy production systems, generally sustainable and green, for later use and above all for the sharing of that energy produced within the community. It is therefore convenient to review the main energy sources, especially in the field of the pilots participating in the project, but without losing sight of other possible energy sources that may not be included in the project. In addition, around the hardware and production infrastructures, a large number of devices are deployed to manage and monitor these energy sources. On the other hand, the ultimate goal of that energy is that it be used and consumed, so there are also an endless number of devices, appliances and household appliances that consume part of that energy, as well as infrastructures connected to the platforms that support energy communities of diffusion and sale that give exit to the surplus energy.

There are three main groups of devices involved in ECs, namely the main infrastructure (generation, storage and distribution), the final consumers and the smart management infrastructure.

In the first one, there is a variety of technologies widely used nowadays in the context of generation. Although renewable energy can be obtained from many other different sources, the most commonly used among ECs are:

- Solar panels.
- Wind power.
- Biomass.
- Geothermal.

In the storage field, there are multiple types of batteries that can work either in a standalone mode or directly managed by inverters or other similar control devices.

All those infrastructure devices (inverters, turbines, batteries, etc.) offer some interface with smart metering support that optionally includes the possibility to control the energy flows. This is directly related to self-consumption, batteries and different working modes depending on the configured requirements/preferences (use part of the energy that is being produced to recharge the batteries in the hours of low energy prices, do not recharge the battery in the hours of high energy prices, etc.).

On the other hand, additional equipment must be taken into consideration in the distribution infrastructure. The minimum functionality that is expected to be offered by these devices is related to smart metering given how relevant it is to monitor the energy flows.

In the consumption side, multiple devices can be involved in both public or private areas. Whether these are legacy or smart devices, the most important aspect to consider here is their impact in energy consumption and how Masterpiece can interact with them, either only by being able to meter their consumption or also by being able to control them (switch them on/off on demand, if necessary).

We can see a reduced list of potential consuming devices to be integrated with Masterpiece:

- HVAC.
- Electrical appliances.
- Lighting systems (indoor in buildings and outdoor in public areas, for example).
- EV chargers.
- Elevators.
- DHW (domestic hot water).

Finally, regarding the smart management infrastructure, it is defined as a combination of IoT gateways, power meters, actuators, etc. The role of IoT gateways is to act not only as data forwarders but also as data adapters, and it is critical since a number of the devices that need to be integrated are legacy devices. This last point is quite common in the context of energy metering, with most of the existing models being compatible with some standard protocols (usually Modbus, although there are others).

However, even with smart devices (WiFi smart sockets, Z-Wave meters/actuators, etc.), some level of adaptation is required to unify the access to the information and convert it to the format specified by the Masterpiece platform. This is one of the tasks that need to be performed at this point, convert the information so that it matches the representation used in the platform (data models).

From a global point of view, it is important to remember the smart management infrastructure will include all the hardware elements mentioned in the previous paragraphs as well as other software elements (agents) that are running directly in the platform. These agents will be in charge of the integration of other data sources.

2.2.3. ICT Communication protocols and standards for ECs

This section details the most relevant technologies, protocols and standards considered in the Masterpiece environment to obtain/store data (with a high degree of quality and reliability), also guaranteeing its traceability and security and data privacy.

Regarding data storage/access, one of the first needs that appears is that the information (coming from external and heterogeneous data sources, such as platforms, IoT devices or sensors from different providers/manufacturers) is stored in a format of homogeneous and standardized representation (offering a solution that aims to be as widely accepted as possible). Based on it, not only will there be a place to store the information, but also, by guaranteeing that all the information is available in the same representation format, it will allow the integration of third-party developments with less effort and even the use of elements of software already developed and that are already integrated into the standard. All this allows for a scalable solution that is not affected by the heterogeneity of the source data or its volume.

In Masterpiece, for data integration and interoperability, accurately defining a data model that meets the needs will be required within the context of energy communities. The data model must be defined in such a way that it can be used in areas such as IoTs, Smart Cities, etc. where the volume of data is significant and very diverse (they can collect data related to energy, weather, device monitoring, etc.).

All of the above leads us to consider the approach of the FIWARE foundation, which is the most relevant EU initiative in this regard. FIWARE's objective is the IoT interoperability of devices, data, applications and services in sectors such as cities and smart buildings, offering open-source solutions and having great support and acceptance from the community. For information modelling, preparing it to be interoperable, FIWARE is promoting the definition of Smart Data Models, with the collaboration of other organizations such as TM Forum, OASC or IUDX. Smart Data Models are based on ontologies (for instance: SAREF) and widely accepted standards are aligned with linked data principles, such as NGSI-LD (Next Generation Service Interface for Linked Data). The goal of Smart Data Models is to provide a common language for data representation that allows developers to create applications that can consume and process data from different sources without requiring extensive integration efforts. As can be seen, FIWARE offers the perfect environment for Masterpiece, enabling the definition of a homogeneous data model, based on open data representation standards, as well as the use of code developments, free of charge and compatible with any application developed that uses of Smart Data Models.

In Masterpiece, the central element of FIWARE will be used, called Context Broker, which stores/represents the data (real-time) coming from external data sources in standard format. Among the different brokers that allow this functionality, Orion-LD (developed by FIWARE) will be used. Orion-LD is an open-source framework that supports the development of smart solutions. Thanks to the HTTP REST/JSON-LD API based on NGSI-LD (Linked Data) defined by the ETSI group specification), Orion-LD makes it possible to register, query and update the desired information, as well as subscribe to changes in it (sending notifications). Furthermore, the use of this component further enables the use of IoT agents based on ETSI NGSI-LD APIs (REST/JSON) to enable high connectivity of heterogeneous entities (i.e., IoT devices and ICT systems). In the same way, for historical storage purposes, native FIWARE historical storage components can be used (as MINTAKA), or an alternative could be the use of Fiware-Cygnus component, which is a connector in charge of persisting data sources in certain configured third-party historical storages, creating a historical view of said data, in this sense, you can store data in Elasticsearch, CKAN, among others..., these components that usually also offer HTTP REST/JSON-API. Fiware-Cygnus component can be also used to persist data in some native FIWARE historical storage components that can't consume directly the notification changes from Orion-LD, this is the case for instance of FIWARE STH-Comet historical storage. The following figure shows an example of the architecture.

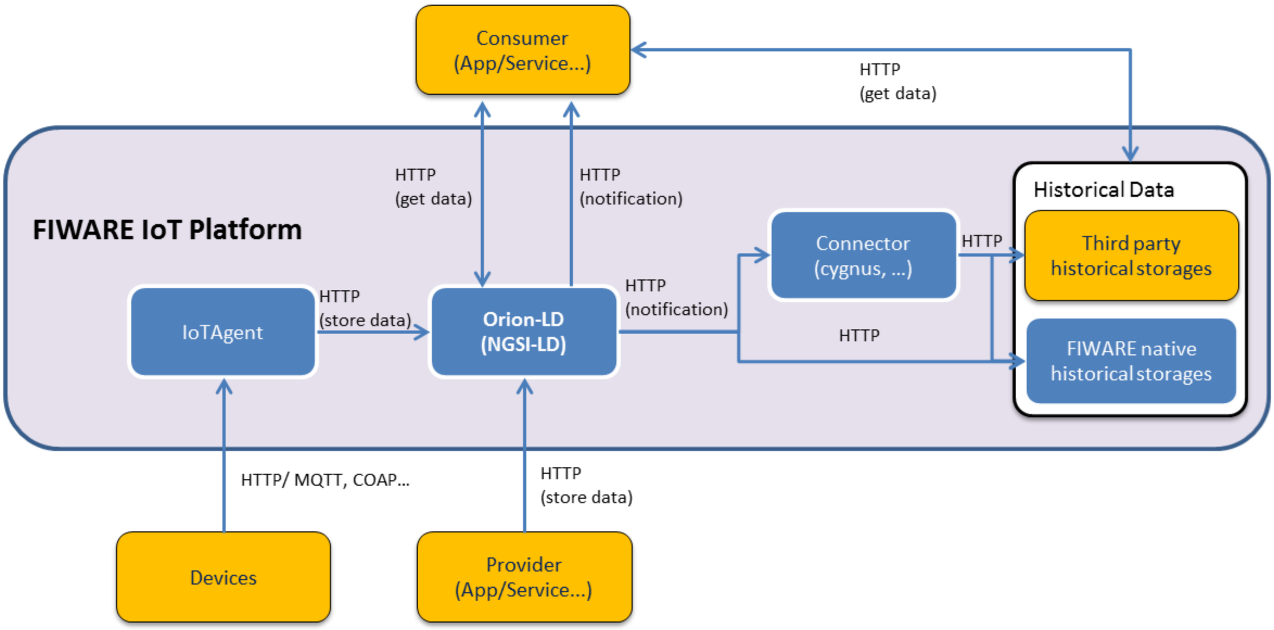

Figure 6: FIWARE IoT Platform

Once the components that will store the information have been defined, the security and privacy of the data must be guaranteed in the accesses, so mechanisms must be established to satisfy these needs so that only those who are allowed have access to the information. All the above makes it possible to define a "security and privacy framework". On the one hand, allows an information management environment that offers scalability/interoperability and high connectivity and. On the other hand, provides a security and privacy engine, being accessible by those elements of the architecture that require it, regardless of whether they are deployed in a pilot environment such as in the Cloud.

The security and privacy engine provides access to distributed data using or implementing Smart Contracts (Blockchain). This engine will be based on an authentication/authorization scheme, which is made up of various technologies/components that allow offering the different needs that are required of it, in this way we have:

- A privacy-preserving identity management mechanism. For this goal the **FIWARE component Keyrock** is chosen. This component is considered for the Identity Manager framework and EAP authentication purposes where all EAP authentication and identity details are configured during the setup stage of the deployment. These details include the user attributes (where the user concept can be understood as a device, application, service...). A user that wants information access needs previously authenticate its credentials with the KeyRock IdM-Manager which returns an KeyRock Token (Auth. Token) is provided to the user.

- A modelling language based on XACML (eXtensible Access Control Markup Language) is used to specify access control policies to the platform. In this sense, **a XACML framework** is used for this purpose. This framework allows to configure access control policies using the properties of data providers or consumers, and it contains mainly these components:

    - **The Policy Management Point (PAP)** is a user interface (UI) to configure access control. This configuration will control obtaining or acting on the information stored in the platform by and the administrator (responsible for this configuration). PAP stores the access control policies in XACML representation.
    - **The Policy Decision Point (PDP)** is the element that, based on the defined XACML Policies, checks if the request for authorization access is compatible with them (issuing a verdict).
- A distributed access control model based on capabilities tokens (DCapBAC) is provided to manage the authorization access. Mainly composed by:
    - The **XACML** Framework (PAP, PDP) mentioned above.
    - **The Capability Manager** is the element for obtaining an authorization token (Cap. Token) by the user side. Before it checks if the current user request is authorized, through the PDP service, it will verify, accessing the Keyrock, if the "Auth. Token" (issued by Keyrock) is valid. This "Auth. Token", attached to the request, determines the specific user that is requiring access to the platform. In case of "Auth. Token" is valid, the Capability Manager will ask the PDP for a verdict (authorization) and if the verdict is positive, it will provide the "Cap. Token" to the requesting user.
    - **The Policy Enforcement Point (PEP)** Proxy captures and handles the requests to the platform for instance to FIWARE Orion-LD Broker or a historical component which offer HTTP REST API. Since the broker and historical components can't evaluate if the "Cap. Token" is valid in a native way (their API don't support it), a specific instance of PEP-Proxy component is employed instead to check "Cap-Token" (included as a header in the request). If the token evaluation is successful, PEP-Proxy forwards the request to the FIWARE Orion-LD Broker or historical component depending on the case.

- A privacy preserving, for requirements as data encryption or group communications, based on **CP-ABE** (Ciphertext-Policy Attribute-Based Encryption).
- An elliptic curve cryptography (**ECC**) optimized for signing and validating tokens distributed between the platform and external entities (i.e. restricted IoT devices and ICT service). It can be used to create and validate the authorization token ("Cap.Token") used by DCapBAC.
- A channel protection solution based on REST/HTTP through open **IETF standardised protocols** as TLS/SSL (i.e. HTTPS) to guarantee integrity and confidentiality in end-to-end private and secure communications with integrity and confidentiality.
- A DLT component (Hyperledger Fabric - **Blockchain**) that guarantees the integrity and traceability of the data since it uses an immutable distributed ledger to store them. This immutable storage ensures data is not tampered with. The access to the distributed ledger by distributed entities, for store or obtain data, is possible through the Smart Contracts implementation. DLT offers a third-party service integration in a trusted way and can be used, between others, for purposes as:
    - storage of the access control policy (XACML framework) storage, allowing the sharing and verification of them.
    - implementation of a financial contract.

The following figure shows an example of a Security and Privacy Engine architecture protecting an Orion-LD API that is conceptually not included in the engine.

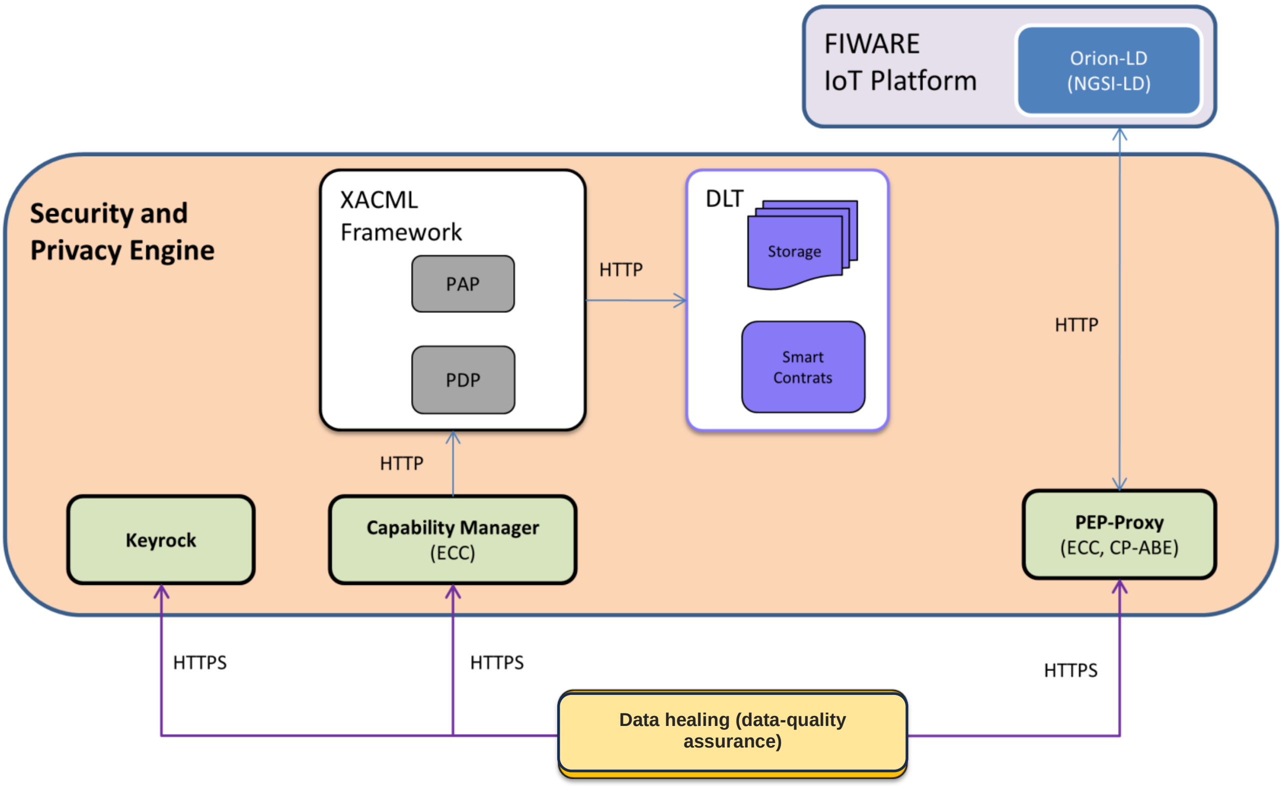

Figure 7: Security and Privacy Engine architecture

The figure also exposes an example of architecture where a third-party component is integrated for accessing to the stored data through the Security and Privacy Engine (Security layer). This data healing component is a data-quality assurance for ECs application domain that will be delivered by CERTH, capitalizing on a related Smart2B H2020 counterpart which focuses on smart appliances applications.

The data healing component will be responsible to detect and mitigate error data such as: duplicates, gaps, temporal repetitions; to apply anomalies detection in a (close-to) real-time (early-warning) and off-line manner, based on synthetic and real-life pilot data. Both univariate and multi-variate Machine-Learning and statistical mechanisms for detection, identification and curation will be investigated.

2.2.4. Preliminary technologies identify for the innovations

This section serves as a compass by synthesizing as a background technologies identified for the innovations of the technological dimension. It is described those that are highly likely to be needed for the developments within the project. The fact that they are in this technological dimension does not implies that they are not useful for the other two dimensions, it is simply a starting point to establish a panoramic to help the development of components.

- **NGSI-LD:** NGSI-LD (Next Generation Service Interface for Linked Data) is a standard developed by the European Telecommunications Standards Institute (ETSI) for representing, querying, and exchanging information about real-world entities in the context of the Internet of Things (IoT) and smart cities [25]. It is an evolution of the earlier NGSI and it has been evolved to better support linked data (entity relationships), property graphs and semantics).

- **XACML:** The eXtensible Access Control Markup Language (XACML) is a standard developed by leading security experts as part of the Organization for the Advancement of Structured Information Standards (OASIS) [26]. It is currently in its third generation. The XACML remains the only standardized way to dynamically enforce authorization by externalizing access controls from applications and databases and using business policies – in what is also referred to as Attribute Based Access Control (ABAC) to govern who can access which data under multiple, fine-grained conditions. At its core, it consists of a standard language, response/request protocol, and reference architecture.
- **Python:** Python is an interpreted, object-oriented, high-level programming language with dynamic semantics [27]. Its high-level built in data structures, combined with dynamic typing and dynamic binding, make it very attractive for Rapid Application Development, as well as for use as a scripting or glue language to connect existing components together. Python's simple, easy to learn syntax emphasizes readability and therefore reduces the cost of program maintenance. Python supports modules and packages, which encourages program modularity and code reuse. The Python interpreter and the extensive standard library are available in source or binary form without charge for all major platforms and can be freely distributed.
- **Java:** Java is a programming language and computing platform first released by Sun Microsystems in 1995 [28]. It has evolved to power a large share of today's digital world, by providing a reliable platform upon which many services and applications are built. New, innovative products and digital services designed for the future continue to rely on Java, as well. Most modern Java applications combine the Java runtime and application together.
- **Visual Studio Code:** Visual Studio Code is a lightweight but powerful source code editor which runs on the desktop and is available for Windows, macOS and Linux [29].It comes with built-in support for JavaScript, TypeScript and Node.js and has a rich ecosystem of extensions for other languages and runtimes (such as C++, C#, Java, Python, PHP, Go, .NET).
- **CP-ABE**: CP-ABE stands for Ciphertext-Policy Attribute-Based Encryption. It is an advanced encryption technique that allows data to be encrypted in a way that access to the encrypted data is controlled based on certain attributes of the users. CP-ABE is a form of attribute-based encryption (ABE) that focuses on controlling access to encrypted data using a policy specified in terms of attributes [30].
- **ECC:** Elliptic-curve cryptography (ECC) is an approach to public-key cryptography based on the algebraic structure of elliptic curves over finite fields [31] . Compared to currently prevalent cryptosystems such as RSA (Rivest–Shamir–Adleman), ECC offers equivalent security with smaller key sizes. Smaller key sizes result in savings for power, memory, bandwidth, and computational cost that make ECC especially attractive for constrained environments.
- **HTTPS REST APIs**: HTTPS is a secure version of HTTP, the protocol used for transmitting data between a web browser and a website. It adds a layer of encryption using SSL (Secure Sockets Layer) or TLS (Transport Layer Security), to protect the data exchanged between the client (typically a web browser) and the server. REST is an architectural style for designing

networked applications. RESTful APIs allow clients (such as web browsers or mobile apps) to interact with server resources using a set of standard HTTP methods such as GET, POST, PUT, DELETE [32]. HTTPS REST APIs adhere to REST principles and also ensure the security and privacy of data transmitted between clients and servers by using HTTPS encryption.

- **Django:** Django is a high-level Python web framework that encourages rapid development and clean, pragmatic design [33]. Django is designed to simplify and speed up building web applications by providing a set of tools, libraries, and conventions for common tasks, allowing developers to focus on writing their application's specific logic. Its focus on reusability, maintainability, and adherence to best practices has made it a go-to choose for developing a wide range of web applications, from small projects to large-scale applications.
- **ReactJS:** ReactJS often referred to as React, is an open-source JavaScript library developed by Facebook [34]. It's used for building interactive user interfaces and web applications quickly and efficiently with significantly less code than with just vanilla JavaScript. With React it is possible to create interactive and dynamic UIs with a relatively simple and organized syntax. It has been widely adopted in the web development community and is used by many companies to build responsive and user-friendly web applications.
- **MongoDB:** MongoDB is a popular open-source, NoSQL database management system designed to store and manage large volumes of unstructured or semi-structured data [35]. It uses a flexible and dynamic document-based model that allows developers to work with data in a more intuitive and adaptable way. The flexibility of MongoDB's document-oriented model and its scalability features make it particularly well-suited for scenarios where the requirements of the application are not completely known upfront or where the data model might change frequently.
- **Angular 14:** Angular is a development platform, built on TypeScript. Angular serves as a platform offering a framework centered around components for the creation of scalable web applications. It incorporates a cohesive set of libraries that encompass an extensive range of functionalities, encompassing aspects such as routing, form handling, interaction between client and server, and more [36] .Additionally, it provides an array of developer tools designed to facilitate the development, construction, testing, and maintenance of your code.
- **Grafana 9.0:** Grafana is an open-source interactive data-visualization platform, which allows users to see their data via charts and graphs that are unified into one or multiple dashboards for easier interpretation and understanding [37]. It provides tools for creating interactive and customizable dashboards, visualizing metrics, and analyzing data from multiple sources. There is the option to query and establish alerts for the data and metrics regardless of their storage location. This allows users to analyze data effortlessly, detect patterns and irregularities, and enhance the efficiency of the workflow.
- **NetCore 7.0:** .NET Core is a framework created by Microsoft that's open-source and works across different platforms. It's tailored for constructing contemporary, high-speed, and easily scalable applications [38]. Its versatility extends to a range of application types, encompassing web applications, APIs, microservices, desktop applications, and more.
- **.NET MAUI:** NET MAUI stands for "Multi-platform App UI" and is designed to enable developers to build native cross-platform applications using .NET and C#. Using .NET MAUI, apps can be developed that can run on Android, iOS, macOS, and Windows from a single shared code-base [39].

- **Syncfusion**: Syncfusion is a software company that provides a wide range of tools, components, and controls for building applications across various platforms. These tools are designed to help developers create rich, interactive, and visually appealing user interfaces for their applications. Syncfusion offers a variety of technologies, including .NET, .NET MAUI, JavaScript Angular, React, and more [40].
- **Microsoft Azure:** Microsoft Azure is a cloud computing platform that makes it easy for developers to create, deploy, and manage digital applications [41]. It offers a wide range of cloud-based services, tools and services across various domains, including computing, analytics, storage, networking, databases, artificial intelligence, and more.
- **MQTT Broker:** The MQTT protocol provides a lightweight method of carrying out messaging using a publish/subscribe model. MQTT is a lightweight messaging protocol designed for efficient and reliable communication between devices, often in scenarios where resources are limited or network connections are unreliable [42]. This makes it suitable for Internet of Things messaging such as with low power sensors or mobile devices such as phones, embedded computers or microcontrollers.
- **Docker:** Docker is an open platform for developing, shipping, and running applications. With Docker, the separation of applications from infrastructure is enabled, allowing software to be delivered rapidly. In the same manner applications are managed, infrastructure can be managed using Docker [43]. The utilization of Docker's approaches for shipping, testing, and deploying code allows the reduction of the delay between the authoring of code and its execution in production.
- **Node-RED:** Within the realm of IoT and automation, Node-RED serves as a visual programming tool. It empowers individuals to seamlessly interconnect devices, APIs, and services. Integration of this tool expedites the creation of intricate workflows, enhancing the potential for innovative applications and solutions to flourish [44].
- **UFTP (Unicast File Transfer Protocol):** UFTP addresses the need for efficient file transfer, particularly for large files within high-speed networks. Engineered for rapid and reliable transmission, UFTP stands as a solution designed to optimize data transfer efficiency within high-capacity network environments [45].
- **Celery Framework and RabbitMQ broker**: The Celery Framework, combined with the RabbitMQ message broker, empowers the asynchronous execution of tasks within distributed systems. This combination streamlines background task execution, optimizing resource utilization and enhancing the responsiveness of complex systems [46], [47].

2.3. Social innovations

The social dimension focuses on the social and human aspects of energy initiatives driven by the energy community. It underlines the importance of attracting, involving and engaging the different profiles that form or may become part of energy communities.

2.3.1. Social profiles within ECs

In our work of identifying the dynamics within ECs, we adopt a qualitative research methodology of considerable depth. This approach entails a thorough examination of various facets of user engagement within these communities, offering us a comprehensive view of their interactions.

We start by identifying user needs, encompassing their needs, requirements as well as their values and aspirations. This includes investigating their behavioural patterns, which explores how users interact with and adapt to the evolving spectrum of ECs. We also explore the values and principles that guide their participation, the overarching goals they aim to achieve collectively, and the driving forces (drivers) that motivate them to actively contribute.

To ensure a comprehensive understanding, we categorize participants based on their roles as regular citizens, energy producers (prosumers), and innovative contributors within the ECs. Furthermore, we consider the specific ECs they are affiliated with, acknowledging that different communities may have varying needs, objectives, and dynamics.

We also consider the concept of "agency," which pertains to their capacity to shape and influence the context within their ECs. Some participants may play a pivotal role in decision-making and community development, while others may have a more passive role.

Simultaneously, we assess the participants' readiness and maturity, recognizing that different individuals and ECs may be at different stages of development and adaptation within the broader energy landscape. Ultimately, our overarching objective is to derive profound insights that will guide the formulation of strategies leading to more effective, tailored, and user-centric energy solutions.

The Intervention Program is designed to enhance participants' understanding and involvement in energy resource sharing, distribution, planning, and sales dynamics. To gauge the success of this intervention, several key performance indicators will be closely monitored and measured.

The objectives of the intervention program include achieving a 30% increase in membership within energy communities, a 20% increase in federated services within each community, and the development of embryonic models of mobility services across the four pilot cases. These objectives have methodological implications for the program's execution.

- Methodology for Engagement and Participation will employ participatory practices to design information display systems integrated with smart meters. The maturity and aspirations of energy communities in the four pilot cases will guide the requirements for engaging various stakeholders and community members in these processes.
- Automation systems will present aggregated data to users based on their usage characteristics and activity hierarchies. These systems will facilitate monitoring, resource aggregation, and simulations of energy distribution and production planning activities. These activities and automation algorithms will be developed through modelling activities in WP3.
- Experimental Plan will be meticulously designed to evaluate the effects and moderating factors of the Intervention Programs. This plan will establish economic, behavioural, and cultural moderators aimed at accelerating the formation of collaborative energy communities. It will encompass monitoring, simulation, planning, and sales tasks to verify participation and behavioural stability within the communities.

Nudging mechanisms will be implemented to activate processes for joining the services, while boosting mechanisms will support the growth of competence, agency, and collaboration. Notably, the Experimental Plan represents the current state-of-the-art in social and behavioural sciences.

We employ nudging as gentle persuasion methods through presenting stakeholders with suggestions and access to a tool designed to make recommendations. This resource aids in recognizing the unique characteristics of people participating in discussions, allowing for the suggestion of communication tactics that easily match each user's inclinations and needs. This customized approach guarantees that the message remains constantly fitting for the specific individual, consequently strengthening their chances of joining and actively involving themselves within the EC.

Through the Intervention Programs, we anticipate defining a set of guidelines to meet diverse requirements for the growth of management competence, social well-being, and sustainability within energy communities. Ultimately, the recommendations derived from these experimental studies will establish new methodological standards for accelerating sustainable innovation models. The results can serve as a blueprint for the scalability of support programs for energy communities, benefiting policymakers and stakeholders alike.

2.3.2. Participatory and inclusion needs and mechanisms [Enrolment]

The path to enrolment in an energy community is a dynamic and multifaceted journey, characterized by several distinct stages that individuals traverse on their route to becoming active participants. This progression unfolds gradually, starting with the foundational awareness stage until reaching a decision-making of enrolment.

We refer to the first segment of this journey as the "pre-adoption" phase. During this stage, citizens embark on a transformative expedition as they move closer towards joining and ultimately adapting innovative energy consumption habits. Within this transformative journey, citizens gain a deep understanding of the core principles linked to ECs, both at the individual and communal levels. They also come to appreciate their unique role in contributing to the EC and comprehend the necessity of adopting novel behaviours that disrupt their traditional daily routines and lifestyles. These transformative transitions frequently arise during what we label as "macro moments," symbolizing pivotal turning points along their energy consumption path.

Profiling assumes a significant role during this stage, providing us valuable insights into diverse profiles and groupings amongst members within the community. This enables us to craft messages and nudging strategies that resonate most effectively with each specific type or cluster, thereby facilitating their progression towards enrolment.

This journey unfolds progressively, beginning with the initial awareness stage and culminating in the pivotal enrolment decision.

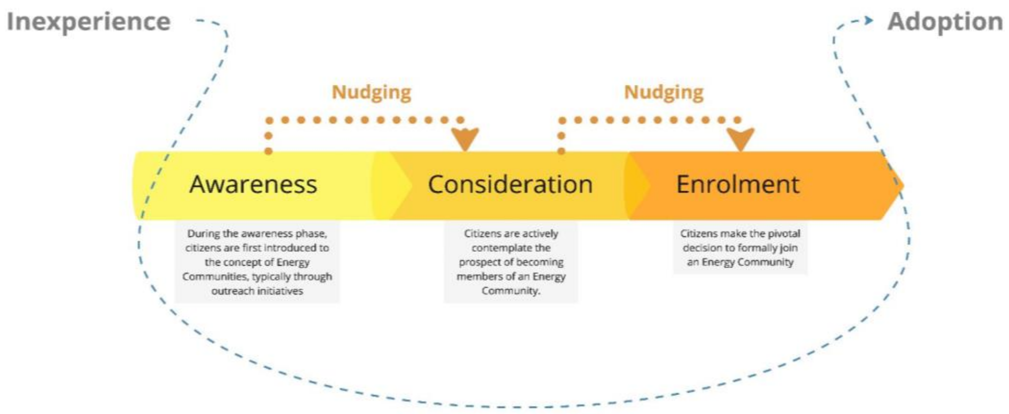

Figure 8: The enrolment journey

- **Awareness:** This marks the starting point of the journey. During the awareness phase, citizens are first introduced to the concept of ECs, typically through outreach initiatives facilitated by the municipality or other key stakeholders. At this stage, citizens are equipped with essential knowledge and awareness concerning environmental sustainability and the intrinsic value of becoming active participants in an EC.
- **Consideration:** As citizens progress, they transition into the consideration phase. Here, they actively contemplate the prospect of becoming members of an EC. Nudging techniques, facilitated through the provision of tailored profiling and clustering tools and information, play a pivotal role in shaping their decision-making processes.
- **Enrolment:** This phase marks the culmination of the journey, where citizens make the pivotal decision to formally join an EC. Here, nudging strategies recommend a personalized communication that selectively influences the enrolment of new members.

2.3.3. Participatory and inclusion needs and mechanism [Engagement]

The engagement journey within ECs is a well-structured process with distinct phases and roles, as it can be seen in the following figure.

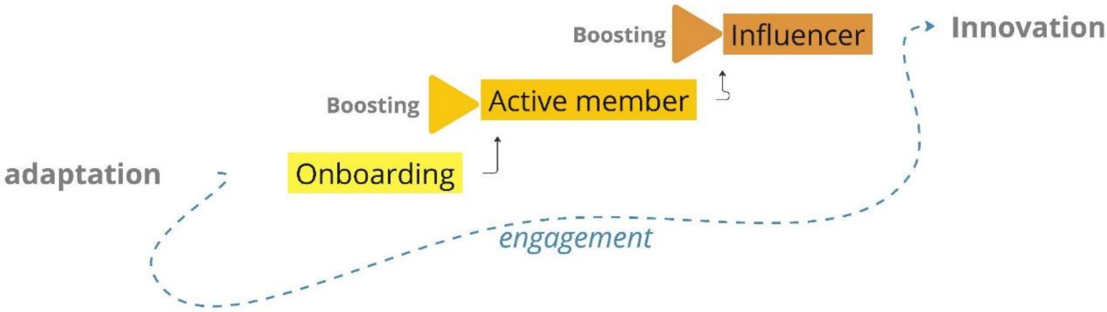

Figure 9: The engagement journey

- **Onboarding Phase:** The journey begins with the onboarding phase, where new members are introduced to novel habits and energy consumption patterns that positively influence their daily routines. This phase sets the tone for their future participation within the EC.
- **Boosting Mechanisms:** During the onboarding process, boosting mechanisms take centre stage. These mechanisms are strategically designed to empower new members with the necessary tools and insights to adapt to new behaviours related to energy consumption, agency, and collaboration within the EC.
- **Member Transformation:** Boosting mechanisms serve as catalysts for member engagement, transforming them from passive members into active participants' eager to contribute within the EC. This phase also lays the foundation for the evolution of some active members into "influencers."
- **Contributions to Growth:** By motivating and guiding others, Influencers contribute to the growth of the EC, aligning with broader goals of social impact and sustainable innovation. Influencers play a significant role within the EC. They act as guides, mentors, and catalysts for both the onboarding process of new members and the advancement of innovation within the EC. Influencers have a pivotal presence and leadership, inspiring not only the smooth integration of newcomers but also higher levels of innovation, collaboration, and sustainable energy practices within the entire EC.

2.3.4. ECs innovation opportunities for management and governance

Our comprehensive desk research, in addition to our insights gathered from the four pilots, underscores the need for a renovated approach when it comes to managing and governing ECs.

Management innovation

In our pursuit of innovative management, we adopt a multifaceted approach to guide users toward embracing novel techniques that harmonize with EC principles. Our approach integrates social planning with boosting mechanisms designed to facilitate effective EC management. These mechanisms are carefully tailored to address the diverse needs of members, whether they are regular participants or more active contributors, and their interactions within the governance structures.

Governance strategies

In the governance arena, we implement two distinct strategies:

- **Bottom-up:** In this approach, EC members and key stakeholders wield influence over governance. They aim to reshape policies in favour of EC creation, operation, and replication. It's essential to empower and boost the morale of EC members, fostering a sense of community and driving their engagement in shaping governance needs and actively pursuing them.
- **Top-down:** Here, innovative policymakers and governing stakeholders take the lead in crafting policies and strategic plans that encourage the establishment of ECs, creating an environment conducive to their growth.

To execute these strategies effectively, we employ social behaviour modelling (Task 3.3) and leverage recommender systems and tools to encourage active participation among community members. Our planning activities encompass defining clear objectives, exploring various alternatives and scenarios, crafting sustainable business models, involving a wide spectrum of stakeholders, addressing constraints and barriers, and ensuring the smooth execution of plans.

This comprehensive approach allows us to nurture innovative management practices and promote participatory governance structures. Both aspects are vital for the successful inception and evolution of ECs. They pave the way for communities to not only thrive, but also drive positive change within their broader energy ecosystems.

2.3.5. Preliminary technologies identify for the innovations

Throughout the previous sections of the subchapter of social innovations, various mechanisms have been discussed that help address different aspects affecting the social dimension. Therefore, in this section, it will be synthesised those identified tools and methods that we can consider as technologies that promote innovation in the respective dimension.

Regarding user aspects, we can find the following methodologies:

- User Needs Assessment: Evaluating the requirements, values, aspirations, and motivations of users to identify their needs and preferences.
- Behavioural Analysis: Examining user behavioural patterns and how they adapt to the changing landscape of ECs, while also uncovering the guiding values and philosophies behind their participation.
- Role Categorization: Classifying participants into distinct roles such as regular citizens, energy producers (prosumers), and innovative contributors within ECs.
- Community Specifics: Considering the unique characteristics, needs, objectives, and dynamics of the specific ECs to which participants belong.
- Readiness and Maturity Analysis: Assessing the preparedness and level of development of individuals and ECs, recognizing that they may be at varying stages of growth and adaptation.

- Agency Evaluation: Determining the ability of participants to influence and shape the environment within their ECs, acknowledging that levels of influence may differ among participants.

In the case of tools covering enrolment and engagement, it is mainly focused on nudging and boosting mechanisms. As it was shown in previous sections, implementing nudging mechanisms to gently persuade users to join services and boosting mechanisms to enhance competence, agency, and collaboration.

3. Preliminary components overview

In the project's aim to empower traditional energy consumers, foster innovation, and create user-centric solutions while pioneering new business strategies, strengthening cybersecurity, and demonstrating the practicality of our innovations through real-life pilots. In the present chapter, it is presented overview of these integral components shaping our vision for the future of energy communities.

Each component is defined by a set of key details, providing a preliminary clear understanding of its role and impact:

- **Technological element title / name:** This identifies the specific component aspect or solution.
- **Corresponding project task:** This outlines the project task associated with the component's development.
- **Technology provider / developer:** The entity responsible for developing or providing the technology.
- **Technology use / purpose:** This describes the primary function or purpose of the technology within the project.
- **End-user type:** We specify the target end-users or beneficiaries who will interact with the technology.
- **Deployment framework:** This indicates the framework or environment where the technology will be implemented.
- **Indicative necessary / minimum inputs:** It details the essential input requirements for the technology to function effectively.
- **Indicative outputs:** It presents the expected outcomes or results generated by the component.

Table 6: Innovative Market mechanisms for incentivizing green and resilient green use

Technological element title / name	Innovative market mechanisms for incentivizing green and resilient energy use
Corresponding project task	WP3 Task 3.1 and 3.2
Technology provider / developer	R2M, UB, UMU (support)
Technology use / purpose	List of market mechanisms available at the local scale for supporting and driving green and energy-efficiency-oriented behaviours, services and business. Market mechanisms (e.g., incentives, EPC schemes, energy network fee deduction, crowdfunding, net-metering or pay-as-you-bid mechanisms, local carbon/energy efficiency credits, etc.) are categorised according to the provider (public, private, and citizens). The tool allows users to simulate the mid-long-term remuneration of each market mechanism according to national and local regulations by inserting basic data on the number of users/EC members, consumption patterns and generation capacity. Users can get access to all information in one (digital) place. AIM: • Incentivise green and energy-efficiency-oriented behaviours, services and business, considering and simulating mid-long-term benefits both in terms of profitability and cost reduction in energy uses • Enhance the feasibility of EC initiatives • Scale-up EC initiatives
End-user type	EC promoters (Municipalities, households, associations, foundations, SMEs, etc.) Aggregators DSO/TSO EC members SMEs Energy market suppliers
Deployment framework	Cloud (remote server)
Indicative necessary / minimum inputs	Consumption/production data of EC members Sociodemographic data of EC members Location (public market mechanisms are strongly locally routed and depend on national/local regulations)
Indicative outputs	Remunerative profile of market mechanisms (single mechanism assessment/mixed mechanisms assessment) based on basic data requirements

Table 7: Community members profiling component

Technological element title / name	**Community members profiling (sociodemographics, technological, energy consumption)**
Corresponding project task	Task 3.4
Technology provider / developer	CERTH, EXP
Technology use / purpose	The profiles can help the operators of the EC get a better understanding of the end users. They can be used to assign proper incentives and penalties to the end user and to give them appropriate suggestions
End-user type	EC operator
Deployment framework	Python 3.8+ exploiting PANDAS, KERAS PyTorch and SCIKIT libraries for machine learning models training
Indicative necessary / minimum inputs	Consumption/production data of EC members Sociodemographic data of EC members Suggestions from EC operators
Indicative outputs	Descriptions, classifications. Can be adapted accordingly: database table, CSV file, XML

Table 8: Profiles clustering / EC modelling component

Technological element title / name	**Profiles clustering / EC modelling**
Corresponding project task	Tasks 3.3, 3.5
Technology provider / developer	CERTH, EXP
Technology use / purpose	The tool will be used to encourage citizens to enter existing ECs
End-user type	Citizens
Deployment framework	Python 3.8+ exploiting PANDAS, KERAS PyTorch and SCIKIT libraries for machine learning models training
Indicative necessary / minimum inputs	Location, preferences, habits of the citizen Information about the existing ECs nearby
Indicative outputs	Recommendations and incentives

Table 9: EC active competition framework

Technological element title / name	**EC active competition framework**
Corresponding project task	Task 3.5

Technology provider / developer	EXP, CERTH, Pilots
Technology use / purpose	By using the profiles and extracted features of the previous tools, this tool will encourage EC members to encage more with the community and take better decisions that will lead to reduce costs and environment friendly behaviours
End-user type	EC operators
Deployment framework	Python 3.8+ exploiting PANDAS, KERAS, PyTorch and SCIKIT libraries for machine learning models training
Indicative necessary / minimum inputs	Consumption/production data of EC members Sociodemographic data of EC members
Indicative outputs	Suggestions, incentives

Table 10: LEVEL(s) and SRI based EC members assessment/evaluation module

Technological element title / name	**LEVEL(S) and SRI based EC members assessment/evaluation module**
Corresponding project task	Task 4.1
Technology provider / developer	CERTH, RDIUP
Technology use / purpose	Streamed and historically logged data can be used to benchmark residential EC members (prosumers) performance in terms of production, consumption, comfort and SRI. Creation of EC cooperatives to facilitate their integration into existing grid systems while ensuring the stability of the energy system and flexibility of ancillary services
End-user type	Residential EC members (prosumers), operators of EC and participants (shareholders), aggregators, DSOs/regulators
Deployment framework	Cloud (remote server), Python 3.8, Django, Reactjs, MongoDB
Indicative necessary / minimum inputs	Energy consumption, Energy production, Indoor temperature, Indoor CO2 levels, Indoor relative humidity, at least at a daily basis granularity (if not higher). SRI questionnaire completed for heating, cooling, ventilation and green generation services, type of assets, location, production puissance, consumption puissance, the profits sharing and voting methods, goals of the EC to be reached, area, regulations
Indicative outputs	Timely-aggregated metrics and indexes (energy performance, generation performance, thermal comfort, air quality, SRI) on demand, EC cooperatives, portfolios, notifications

Table 11: MEET app component

Technological element title / name	MEET app
Corresponding project task	Task 4.1
Technology provider / developer	R2M
Technology use / purpose	A mobile app offering services to enter and cooperate into an E
End-user type	EC members / EC Consumers EC promoters (Municipalities, households, associations, foundations, SMEs, etc.) DSO/TSO
Deployment framework	Mobile Devices (OIS & ANDROID) on the client side, and then cloud PYTHON 3.8 on a remote server for the backend
Indicative necessary / minimum inputs	Data existing energy communities, API insert & delete community members, incentives
Indicative outputs	Services; subscription new community members or new energy community; spread the Masterpiece toolbox

Table 12: Simulation & DSS toolkit

Technological element title / name	Simulation & DSS toolkit
Corresponding project task	Task 4.2
Technology provider / developer	ALWA, RDIUP, (AMU)
Technology use / purpose	The toolkit will be composed by two modules: the LIBRA CE SIMulator by ALWA and the Sustainable Planning Tool (SPT) by AMU/RDIUP. A web application based on ALWA's LIBRA CE platform will provide information for the economic evaluation of the EC as-is versus to-be conditions with extra (renewable) power generation sources and members. It will calculate commonly used KPIs and give a preliminary assessment of the EC in terms of technical/economic feasibility. In particular, it can show whether the specific EC is a profitable investment or not, considering in particular the typical energy production and consumption profiles of EC element to potentially aggregate. Although originally designed for the Italian market/regulatory framework on ECs, the module will be used for simulation purposes in other countries (e.g., Sweden, Turkey) for establishing potential reference benchmarks. The SPT (Sustainable Planning Tool) includes the different actions and size of energy system components, and suggests recommendations to make better decisions. It will interact with

	the module developed by ALWA for simulation and visualisation. The SPT will also be used for optimal energy asset size recommendation mainly according to French regulation. The backend of the SPT will be used as shared API and database if needed.
End-user type	Local authorities, DSOs, Flexibility market operators, Stakeholders, Energy planners, Decision makers, EC operators
Deployment framework	LIBRA CE SIM: Angular 14, Grafana 9.0, NetCore 7.0, MS Azure SQL Server, Azure Cloud, Azure B2C SPT: Django, Reactjs, MongoDB
Indicative necessary / minimum inputs	Building information, electricity consumption from utility bills, distributed energy resources characteristics, financial parameters, start configuration, metrics, consumption, energy system, storage system, location, portfolios (composition) of the ECs assets
Indicative outputs	Suggestions, scores, decisions, actions, best practices

Table 13: REC management platform

Technological element title / name	**REC management platform**
Corresponding project task	Task 4.3
Technology provider / developer	ALWA
Technology use / purpose	A web application that will showcase the configuration, administrative status, internal governance, and technical/economic performance of the managed ECs. It will support rules-editing for the custom allocations of the incentive-based revenues/profits and receive data from IoT devices/parallel metering infrastructure (for consumption and production) for all necessary computations.
End-user type	EC members, EC operators/managers
Deployment framework	Angular 14, Grafana 9.0, NetCore 7.0, MS Azure SQL Server, Azure Cloud, Azure B2C (plus Microsoft .NET MAUI and Syncfusion for MAUI for the mobile app to convey information to EC members)
Indicative necessary / minimum inputs	Data from the IoT devices/parallel metering infrastructure, personal data from the EC members (consumers, prosumers), geolocalization of EC assets (consumption/production), energy contract parameters, fiscal data from the energy authority
Indicative outputs	Interactive reports and dashboards.

Table 14: Artificial intelligence mechanisms to support community management

Technological element title / name	**Artificial Intelligence mechanisms to support community management**
Corresponding project task	T4.3
Technology provider / developer	UMU
Technology use / purpose	This component, driven by artificial intelligence algorithms, provides a set of functionalities for the administration and management of ECs. Its outcomes facilitate the identification of investment opportunities in energy efficiency and sustainable technologies, promote transparency in decision-making, and enhance efficiency in resource and energy management. Furthermore, techniques such as forecasting can play a pivotal role in EC management by predicting future energy consumption patterns.
End-user type	EC members, EC operators/managers
Deployment framework	Python 3.8, Pycaret (scikit-learn, XGBoost …)
Indicative necessary / minimum inputs	energy consumption, economic efficiency of DER, Energy tariffs, weather forecast, regulations
Indicative outputs	DER performance analysis, energy consumption forecasts, resource management recommendations

Table 15: Real-time aggregated flexibility policy optimization tool

Technological element title / name	**Real-time aggregated flexibility policy optimization tool**
Corresponding project task	Task 4.4
Technology provider / developer	CERTH
Technology use / purpose	Generates the optimal demand profile (day-ahead) taking into account demand response signals (from the DSO), available RES generation, energy tariffs, available thermal flexibility, by employing a hierarchical optimization approach (centralized EC-level, decentralized EC-member level) without jeopardizing individual prosumers comfort
End-user type	DSOs, Flexibility market operators, Grid operators
Deployment framework	Python 3.8+ exploiting PANDAS, KERAS PyTorch and SCIKIT libraries for reinforcement learning or machine learning models training
Indicative necessary / minimum inputs	Weather conditions and forecasts, Energy consumption both at EC member and EC total level. Energy tariffs and incentive

	mechanisms signals. Flexibility estimations or declarations (according to EC members convenience). Numerical inputs from Task 4.3
Indicative outputs	Scheduling demand and managing flexibility both at EC member and EC overall levels

Table 16: Demand Response Management Framework

Technological element title / name	**Demand Response Management Framework**
Corresponding project task	T4.4
Technology provider / developer	UMU
Technology use / purpose	The role played by this component is the execution of Demand Response events at the EC member level as it is responsible for implementing an intelligent control strategy on thermal loads. This strategy has a direct impact on the planned modification of the energy demand curve, with the fundamental objective of achieving an optimal curve that benefits both individuals and the community as a whole.
End-user type	DSOs, Flexibility market operators, Grid operators, EC members
Deployment framework	Docker Engine, Python 3.8, Celery, RabbitMQ, MongoDB
Indicative necessary / minimum inputs	Optimized EC-DR Scheme (peak shaving, turnover optimization)
Indicative outputs	Smart thermal demand schedule and flexibility execution at EC member level

Table 17: Micro-grid load control for EC efficiency

Technological element title / name	**Micro-grid load control for EC efficiency**
Corresponding project task	Task 4.4
Technology provider / developer	CERTH
Technology use / purpose	It generates optimal (in terms of energy and comfort/convenience) control signals for actuatable / controllable EC member or EC overall loads, in an automated manner. It can potentially also generate bulker control recommendations to be manually applied by EC member and operators.
End-user type	EC members, EC operators
Deployment framework	Cloud (remote server), Python 3.8

Indicative necessary / minimum inputs	Weather conditions and forecasts, EC members convenience and flexibility, Energy consumption both at EC member and EC total level. Control signals from actuatable loads (heating, cooling, EV charging).
Indicative outputs	Real-time control signals to be actuated to specific loads

Table 18: Secure energy flow monitoring component

Technological element title / name	**Secure energy flow monitoring**
Corresponding project task	Task 4.5
Technology provider / developer	UMU
Technology use / purpose	Real-time monitoring of energy flows, integrating advanced encryption and security technologies. Ensures Data integrity and privacy regarding energy consumption and generation within the EC.
End-user type	EC members, energy managers, service providers
Deployment framework	Docker and docker-compose
Indicative necessary / minimum inputs	NGSI-LD API to access to the data Consumption/production data
Indicative outputs	NGSI-LD secured API

Table 19: FIWARE IoT platform

Technological element title / name	**FIWARE IoT platform**
Corresponding project task	Task 4.5
Technology provider / developer	ODINS, ALWA
Technology use / purpose	A platform with specific data models, based on standard data format, that offers an HTTP API REST to reduce the integration effort from other federated projects and future ECs. In this sense, it offers an environment where the data can be stored an obtained, ensuring their traceability.
End-user type	Any
Deployment framework	Cloud (remote server). Docker and docker-compose technologies.
Indicative necessary / minimum inputs	HTTP requests to store/access data from any component that requires it, for instance IoT devices measurements…
Indicative outputs	Offers an HTTP API REST for accessing to the data.

Table 20: Security and Privacy Engine

Technological element title / name	**Security and Privacy Engine**
Corresponding project task	Task 4.5
Technology provider / developer	ODINS
Technology use / purpose	An engine that provides access to distributed data using or implementing Smart Contracts (Blockchain). This layer will be based on an authentication/authorization scheme, which is made up of several technologies/components that allow offering the different needs that are required, such as secure communication, preservation of identity privacy, data privacy, and financial transactions.
End-user type	Any
Deployment framework	Cloud (remote server). Docker and docker-compose technologies.
Indicative necessary / minimum inputs	HTTPS requests to store/access data from any component that requires it, for instance IoT devices measurements…
Indicative outputs	Offers an HTTPS API REST for accessing to the data.

Table 21: Data Healing component

Technological element title / name	**Data Healing (data-quality assurance)**
Corresponding project task	Task 4.5
Technology provider / developer	CERTH
Technology use / purpose	Lots of data from various sources will be used in the project. Proper filtering will help in accurate results for decision-making, training, assessment and other data-consuming services.
End-user type	Any
Deployment framework	Cloud (remote server), Python 3.8
Indicative necessary / minimum inputs	Live-streamed field observations and measurements from the IoT devices (through the FIWARE IoT platform foreseen in T4.5 as well).
Indicative outputs	Close to real-time (every hour or so) healed (filtered and imputed) streams of data measurements to restore their quality

4. INTERNAL COMPONENT TEMPLATE

In order to maintain a sound organised project component management environment, it has been developed the internal component template. This template serves as an all-inclusive guide approach that assists in collecting and organizing essential information about each component that will be used in the project. The template does not present the specifics of each component, but rather the fields that will be used to gather detailed information about them. It is presented in the Appendix: Internal Component Sheet. The Internal component template has been designed to establish a cohesive standard for documentation, offering a uniform approach to collect intricate details about the components.

This template is divided into four primary sections: **General Section** (highlighted in **green**), Input **Parameters Section** (in **blue**), **Output Parameters Section** (in **red**), and **Other Requirements/Assumptions Section** (in **yellow**). Each of these sections in the template focuses on unique aspects of a component, ensuring that every detail from fundamental identifiers to nuanced technical and functional requirements is captured systematically.

In the General Section, fundamental information about the component is requested. This info includes details about partner roles for each corresponding component, unique component ID, descriptions and information about input and output connections, among other items. Moreover, this section requests information about software and hardware, along with the component's communication requirements and its development status. The Input and Output Parameters Sections, both follow a similar structure, starting with a brief description, followed by data type and format, value range and frequency for both parameters, leading to source data component for the input part and destination component for the output part. Uniquely in the input section, an additional request aims to discern the confidentiality level of the input data. The final section, Other Requirements/Assumptions, addresses potential additional considerations regarding the corresponding component. It includes providing general information about the requirement or assumption such as its tentative ID, involved partners, type, priority/importance, and description, along with other additional information presented in the template.

This initial version of the internal component sheet will help to ensure that all components are accounted for, understood, and effectively tracked. The last goal of this initiative is to promote better organization, efficient resource allocation, and good internal execution concerning these project components.

Deliverable D4.1 will contain a first version of the Internal component template, duly filled in with the information currently available from the related partners.

5. ARCHITECTURE MOCK-UP

The project concept is being built upon three dimensions, as described at the start of this deliverable. Moreover, regarding this aspect, additional information can be found in previous deliverables (e.g., D2.1). Therefore, the actual chapter aims to synthesise the conceptual landscape of the project's ICT platform without delving into specific technical details.

The ICT platform is presented in an architectural blueprint format in the following figure.

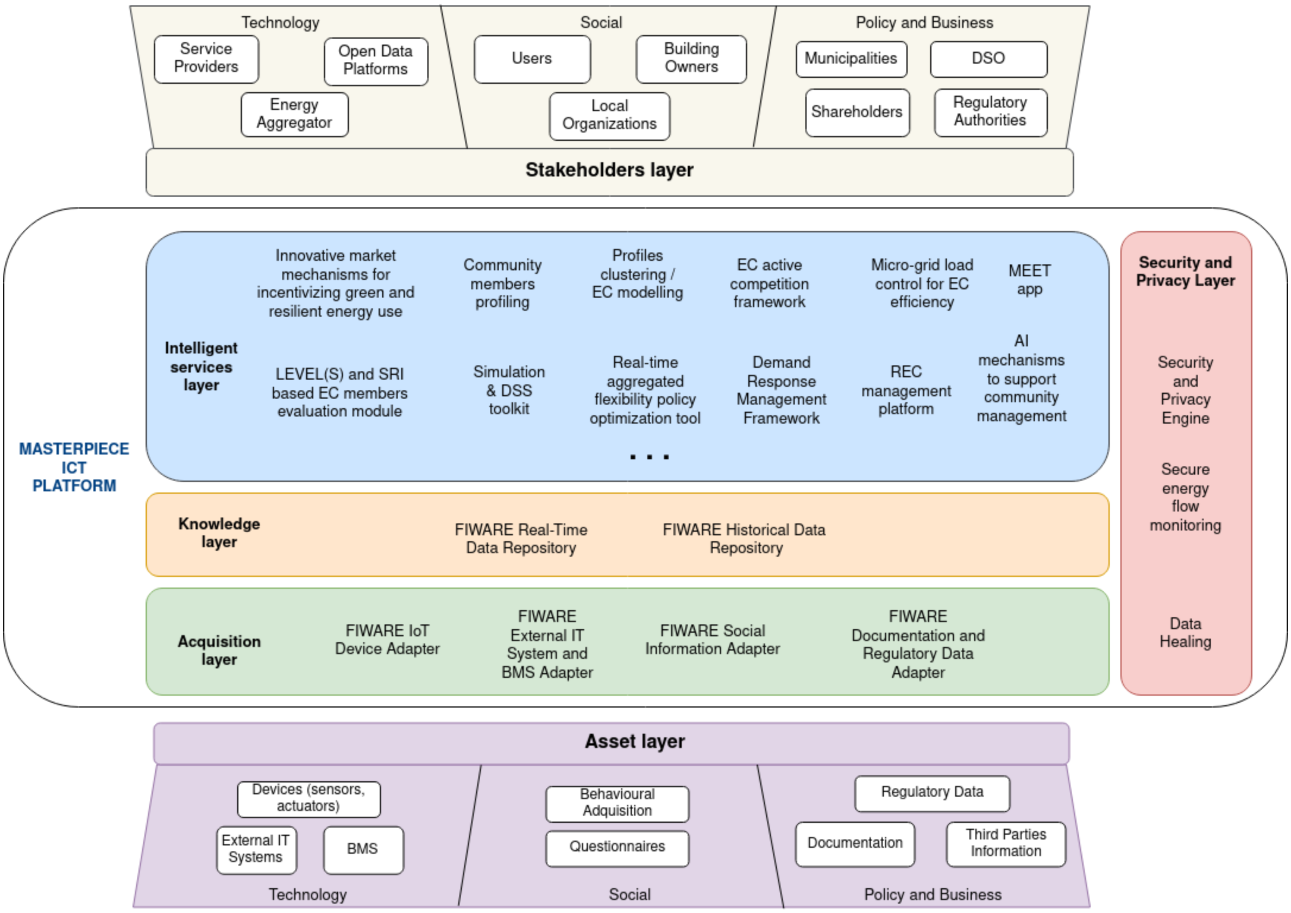

Figure 10: High-level architecture mock-up of Masterpiece ICT platform including features and tentative excemplary components in each layer

The platform is composed of three horizontal layers: **Acquisition**, **Knowledge**, and **Intelligent Services** layers, together with the **Security and Privacy layer** which is the vertical one. Concurrently, the platform is associated with two additional external layers: The **Asset layer** and the **Stakeholder layer**. As depicted in the figure of the platform, both layers are distinguished across the three dimensions, showcasing some examples of potential assets and stakeholders for each of them.

The Asset layer will provide inputs to the Acquisition layer, where various adapters and devices are located to acquire data from different sources and systems, with the purpose of processing and using it later on. This Acquisition layer will feed into the Knowledge layer. This layer involves repositories of historical and real-time data, as well as tools for processing and analysing the aforementioned data. In the Knowledge and Acquisition layers, there are components powered by FIWARE that allow the integration and management of data following the data models and standards (NGSI-LD) required in the platform. These components powered by FIWARE compose the "FIWARE IoT platform" defined in the previous section. Subsequently, Knowledge layer fed the Intelligent Services layer, which contains various functionalities and services as it is shown in Figure 10.

By combining the different layers, the services will be developed to be offered within and outside the energy communities. These services will be directed towards the different stakeholders of the three dimensions, such as users, service providers, or municipalities among the long list of stakeholders considered (in D2.3, a preliminary approach to the identified stakeholders can be seen), in chapter 3 of this deliverable, the stakeholders related for each component are found more precisely.

In conclusion, as can be observed in the figure above, the ICT platform mock up is within the concept of the three dimensions, from the data source layer to the recipient of the services, whether for direct or indirect use.

6. CONCLUSIONS

The present deliverable shows the three key dimensions of the framework of the project focusing on policy and business innovations, technological innovations, and social innovations. By doing so, it lays the foundation for the subsequent technical and functional aspects of the project, particularly in the upcoming work packages WP3, WP4, and WP5.

Throughout this document, we have delved into each dimension, providing a comprehensive overview of the various elements that shape the landscape of EC. In the realm of policy and business innovations, it is described the existing legislative frameworks and business models at both EU and national levels, shedding light on the key mechanisms that drive EC initiatives. In the technological innovation's subchapter, it is synthetised the current status of pilot cases and its pilot sites. Moreover, it is described the hardware requirements essential for ECs, the ICT communication protocols and standards necessary for seamless and secure integration. In the case of the social innovations subchapter, it has been underscored the importance of understanding the social dynamics within ECs pointing out user engagement aspects and the overview of the intervention program. In addition, it was defined the enrolment journey in a EC aimed to inform, persuade and facilitate individuals decisions to become active participants in these ECs. Furthermore, the phases of the engagement journey were described, playing a crucial part in fostering active participation within ECs. Focusing on the management and governance area it was established fresh approaches to have healthy EC environments.

In each of these sections there is a subsection for the identification of preliminary technologies. This subsection helps to synthesize the foundations of those technologies, whether they are tools or mechanisms, that can facilitate and support developments within the three-dimensional concept in the project environment.

To facilitate future work and ensure that all team members are aligned in their understanding of the project's conceptual framework, we have included a preliminary components overview chapter. There were conceptually described 16 components varying in their purposes and level of functionalities. Next chapter described a first internal component template that will serve for collecting detailed technical information on project components.

Lastly, the high-level architecture mock-up provides a visual representation of the ICT platform to be followed within the project. In this blueprint architecture it is combined the Asset Layer with the Acquisition, Knowledge, Service and Privacy and Security layers to develop and offer several services and functionalities to the different stakeholders either outside or inside ECs. This representation aids in conveying in the project the same path when the development of the different components will take place regarding WP3 and WP4.

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APPENDIX: INTERNAL COMPONENT SHEET

INTERNAL COMPONENT SHEET	
Component Name	Name of the component.
Relevant Project Task	Indicate the WP number and the task relevant to the component (e.*g., WP2 – T2.5).*
Partner involves and their role	Mention the partner(s) (acronym) involved in the component and their role: *owner, designer, developer, support and/or leading partner.*
Final users	Mention to which end users the component is addressed.
ID	Indicate a tentative identifier that will be given to the component (acronyms or abbreviations of the component in capital letters). *E.g., ID of the Flexibility Engine component: FLEXENGINE.*
Architectural Module / Layer	Indicate in which ICT module and layer is the component from the Architectural proposal.
Type	*E.g., SW Functionality / Holistic Platform (APIs, brokers) / Methodology, etc.*
Brief conceptual description (100-200 words)	Give a description that involves: 1. Objective/purpose. 2. Gap the component solves. 3. Need for this component.
Brief technical description (100-200 words)	A concise technical description about how the component will be developed / implemented.
Indicative web sources / Publications	If there is any, provide relevant information that gives explanation and illustration of the component, *e.g., links to documents, publications, etc.*
Input Connections & Interfaces	Give the name of other component/tools from which receives input.

<table>
<tr><td colspan="2"><u>Output Connections & Interfaces</u></td><td>Give the name of other components/tools that receive input <u>from this component.</u></td></tr>
<tr><td colspan="2"><u>Replicability level</u></td><td>Indicate the level of replicability: high, medium or low.</td></tr>
<tr><td colspan="3"><u>Input Parameters</u>
(Fill this table with as many Input parameters as necessary)</td></tr>
<tr><td rowspan="5">Input parameter</td><td><u>Short Description</u></td><td>Short description of the input parameter.</td></tr>
<tr><td><u>Data Type and Format</u></td><td>Indicate the data type and format of this parameter. e.g., Integer, float, double, text document, audio file, source file, script, binary executable file, archive file, database table, CSV file, XML, JSON etc.</td></tr>
<tr><td><u>Confidential aspect</u></td><td>Mention if there is any special confidential aspect to consider regarding the input parameter.</td></tr>
<tr><td><u>Value Range & Frequency</u></td><td>Provide the measurement unit, range of values and frequency-sample rate for this input parameter. If applicable, specify when the data is produced, e.g., "On demand".</td></tr>
<tr><td><u>Source Data Component</u></td><td>Indicate the component, module or figure that receives input data to this parameter.</td></tr>
<tr><td colspan="3"><u>Output Parameters</u>
Fill this table with as many Output parameters as necessary</td></tr>
<tr><td rowspan="3">Output parameter</td><td><u>Short Description</u></td><td>Short description of the output parameter.</td></tr>
<tr><td><u>Data Type and Format</u></td><td>Mention the data type and format of this parameter. E.g., Integer, float, double, Text Document, audio file, source file, script, binary executable file, archive file, database table, CSV file, XML, JSON etc.</td></tr>
<tr><td><u>Value Range &</u></td><td>Provide the measurement unit, range of values and frequency-sample rate for this input parameter. If</td></tr>
</table>

	Frequency	applicable, specify when the data is produced, *e.g., "On demand".*
	Destination Component	Indicate the destination component/module/figure that receives input data from this parameter.
Software Requirements / Development Language		Specify any software requirements related to this internal component, name the Programming Languages that are used during the development of the component. Name third party software dependencies, e.g., libraries, programs, systems. Name (if applicable) other different entities that this component requires to operate, *I.e., other systems, software programs.*
Software Execution Environment		List anything that the component requires to run, it could be a computer system that runs over hardware and executes programs, *e.g., an operating system like Windows 10 or Ubuntu 20.04, a virtual machine, like Java VM 1.8+, a container service like Docker, etc.*
Hardware Requirements		Specify what hardware requirements are of the module, give specifications about the hardware requirements which are necessary for the best functionality of the component. (In case it needs any special/dedicated hardware that is included in the hardware specification, it can be included also here as a reference. E.g., *DHT11 temperature and humidity sensor*).
Communications		Name specific communication requirements either for data input or for data output, e.g., communication protocols or standards that must be compliant, *RESTful services for historic data exchange*, *NGSI-LD API services for real-time communication*, communication bandwidth required in Mbps/Gbps.

<table>
<tr><td colspan="2"><u>Component Development Status</u></td><td>Select one from the following status:
Already developed.
Partially developed.
To be developed from scratch.</td></tr>
<tr><td colspan="3"><u>Other Requirements/Assumptions</u></td></tr>
<tr><td rowspan="8">Title/short name for this requirement/assumption</td><td><u>Tentative ID</u></td><td>Give a unique ID for this requirement/assumption (Component ID + - + R + number). E.g., FLEXENGINE-R1.</td></tr>
<tr><td><u>Partner</u></td><td>Indicate the project partner (s) (acronym) that specifies the requirement/assumption.</td></tr>
<tr><td><u>Type</u></td><td>Choose one from the following types:
Functional Requirement.
Non-Functional Requirement.
Assumption.</td></tr>
<tr><td><u>Priority / Importance</u></td><td>One of the following:
<u>Must</u>: The tool must implement this function / meet this requirement.
<u>High</u>: The system should implement this requirement (some deviation from the requirement as stated may be acceptable)
<u>Low</u>: The system should implement this requirement but can be accepted without it.</td></tr>
<tr><td><u>Description</u></td><td>Indicate the intention of the requirement/assumption.</td></tr>
<tr><td><u>Rationale</u></td><td>Give justification of the requirement/assumption.</td></tr>
<tr><td><u>Supporting Materials</u></td><td>If there is any, provide relevant information that gives explanation and illustration of the requirement/assumption, e.g., links to documents, publications, etc.</td></tr>
<tr><td><u>Tentative scheduling</u></td><td>Tentative scheduling of accomplishment (e.g., M12). (Only for requirements)</td></tr>
</table>