WeForming

WEFORMING SERVICES CO-CREATION, BUSINESS MODELS, FUNCTIONAL SPECIFICATIONS AND REFERENCE ARCHITECTURE (1ST VERSION)

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MODELS, FUNCTIONAL SPECIFICATIONS AND REFERENCE ARCHITECTURE (1ST VERSION)

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ABBREVIATIONS

Abbreviation	Description
ACER	**Agency for the Cooperation of Energy Regulators**
aFRR	**Automatic Frequency Restoration Reserve**
AL	**Artificial Inteligence**
BACnet	**Building Automation and Control Network**
BEMs	**Building Energy Management Systems**
BM	**Business Model**
C-COOP	**Community Cooperative**
CEC	**Citizen Energy Community**
CHP	**Combined Heat and Power**
CIM	**Common Information Model**
CoAP	**Constrained Application Protocol**
DER	**Distributed Energy Resources**
DLT	**Distributed Ledger Technologies**
DR	**Demand Response**
DSO	**Distribution System Operator**
EaaS	**Energy as a Service**
EES	**Energy Storage Systems**
EMS	**Energy Management System**
ESA	**Energy Service Agreement**
ESCO	**Energy Service Company**
ESPM	**Energy Market Standard Profiles**
ETSI	**European Telecommunications Standards Institute**
FCR	**Frequency Containment Reserve**
FiP	**Feed-in-Premium**
FiT	**Feed in Tariff**
FSP	**Flexibility Service Provider**
GDPR	**General Data Protection Regulation**
HVAC	**Heating, Ventilation and Air Conditioning**
IEC	**International Electrotechnical Commission**
IED	**Intelligent Electronic Device**
IFS	**Innovative Financing Schemes**
iGFB	**Intelligent Grid Forming Building**
IoT	**Internet of Things**
ISO	**Independent System Operator**
JSON	**JavaScript Obejct Notation**
M2M	**Machine-to-machine**
MESA	**Managed Energy Services Agreement**
mFRR	**Manual Frequency Restoration Reserve**
ML	**Machine Learning**
MQTT	**Message Queuing Telemetry Transport**
NGO	**Non-governmental Organisation**
NRM	**New Revenue Models**

OBF	**On-bill Financing**
OPC US	**Open Platform Communication Unified Architect**
OSS	**One Stop Shop**
P2P	**Peer-to-peer**
PaaS	**Product as a Service**
PACE	**Property Assessed Clean Energy**
PAYS	**Pay-as-you-save**
PV	**Photovoltaic**
R&D	**Research and Development**
REC	**Renewable Energy Community**
SAREF4EVER	**Smart Appliances REFerence ontology for energy**
SME	**Small to Medium Enterprises**
SSL	**Secure Sockets Layer**
SWOT	**Strength, Weakness, Opportunity and Threat**
TLS	**Transport Layer Security**
ToU	**Time-of-Use**
TSO	**Transmission System Operator**
V2G	**Vehicle to Grid**
VPP	**Virtual Power Plant**
XML	**eXtensible Markup Language**

Executive Summary

The report examines the adoption of smart grid technologies in the EU and the role of end users, highlighting challenges and strategies for public engagement (Chapter 2). It discusses the importance of educating building users, identifying barriers, and engaging end users through different methods. To better understand the views of end users on iGFBs, a survey was distributed among demo users. It revealed users interest in energy efficiency but a lack of knowledge about smart grid technologies. The chapter concludes by emphasizing that addressing knowledge gaps, costs, and security concerns is crucial for the successful implementation and widespread adoption of smart grids in both commercial and residential buildings.

This report also discusses several novel Business Models (Chapter 3) have been analysed for single-use and multi-use iGFBs. This report provides an overview of existing revenue opportunities across Europe, highlighting the development of Citizens Communities, Mobility Initiatives, Commercial Buildings, and Industry. The regulatory situation is analysed showing in Belgium, Croatia, Germany, Greece, Luxembourg, Portugal and Spain, underscoring diverse regulatory landscapes across these countries, each facing unique challenges and making varied progress towards efficient energy management and integration of innovative energy systems. The analysis then delves into potential future business models for both single-use and multi-use iGFBs, exploring core functionalities such as thermal storage optimization and solar PV self-consumption, identifying stakeholders like building managers and grid operators, and proposing business models following the concepts of One Stop Shop Concept (OSS), Product as a Service (PaaS), Innovative Financing Schemes (IFS) and New Revenue Models (NRM) to capitalize on the distinctive advantages of these buildings while tackling integration, cost-benefit analysis, and risk assessment challenges. A SWOT analysis and the Lean Model Canvas is provided for each of the Business Models.

The interoperability aspect is highlighted throughout the report, particularly on Chapter 4. Interoperability in modern energy systems is essential for efficient and sustainable energy management, enabling seamless data exchange and functional compatibility across diverse technological platforms. This ensures effective collaboration between consumer interfaces, distributed energy resources (DERs), and large-scale utility plants. Driven by market demands and global shifts towards renewable energy and smart grids, interoperability facilitates optimal resource utilization, enhances grid stability, and supports the integration of renewable energy sources. Standardization bodies like ETSI play a crucial role in developing and validating interoperability standards, which promote regulatory compliance and foster innovation. The adoption of advanced integration technologies, such as microgrid controllers, building energy management systems (BEMS), and edge computing platforms, further enhances system efficiency and reliability. Robust interfaces underpin these systems, enabling real-time data analysis and decision-making, which are pivotal for maintaining grid stability, optimizing energy use, and advancing sustainable energy goals.

Finally, details the development process for the WeForming Reference Architecture (RA) is addressed on Chapter 5. It commences with a comprehensive analysis of existing reference architecture models, with a particular focus on those emanating from European initiatives and research projects relevant to this field. Subsequently, the chapter explores the rationale behind utilizing Data Spaces within the context of intelligent Grid-Forming Buildings (iGFBs). The proposed approach centres on the core value proposition of sovereign data management, secure and environmentally conscious data sharing, peer-to-peer collaboration, inclusive power demand response programs, high-fidelity data descriptions, and user-centric service catalogues. Finally, Chapter 4 presents the initial version of the WeForming RA itself, outlining both the data flow perspective and the logical definition of its hierarchical structure.

1. Introduction

1.1. Context and Scope

This document presents an initial exploration of the WeForming project's co-creation activities, including the identification of stakeholder needs and desired functionalities for intelligent Grid Forming Buildings (iGFBs). It explores potential business models for iGFBs and identifies the necessary interfaces for achieving seamless communication and data exchange between different devices and stakeholders within these systems. Finally, it introduces a proposed System Architecture that serves as a role model for iGFBs stakeholders to develop a pan-European sovereign, secure, and environmentally friendly data-based iGFB ecosystem. It is highlighted that Grid Forming Buildings are buildings that not only have the technical capacity to support the grid by increasing or matching its capacity but can also communicated with the smart grid in order to optimize decision making and its operation at different time scales.

1.2. Content and Structure

The report begins by focusing on user adoption and public engagement strategies for iGFBs. It highlights the importance of educating building users about smart grid technologies and overcoming knowledge gaps. The chapter emphasizes addressing user concerns regarding cost, security, and understanding the benefits of iGFBs for successful implementation in both commercial and residential settings.

The report continues by diving into potential business models for iGFBs, analyzing existing revenue opportunities across Europe. It explores models for various applications, including citizen communities, mobility initiatives, commercial buildings, and industries. The chapter also examines the diverse regulatory landscapes across several European countries, highlighting the challenges and progress made towards efficient energy management and integration of innovative energy systems. It proposes future business models considering functionalities like solar energy use and thermal storage optimization. The chapter concludes with a SWOT analysis and a breakdown of each model using the Lean Model Canvas framework.

In the third part the focus is on the importance of interoperability for iGFBs. Seamless data exchange and compatibility across different technological platforms are crucial for efficient and sustainable energy management. This chapter explains how interoperability fosters collaboration between consumers, energy sources like solar energy, consumers and the smart grid. It highlights the role of standardization bodies and adoption of advanced technologies like microgrid controllers and building energy management systems in enhancing system efficiency and reliability.

The fourth part details the development process for the WeForming Reference Architecture (RA). It explores existing reference architecture models and proposes an approach utilizing Data Spaces for secure and user-centric data management within iGFBs. The chapter concludes by presenting the initial version of the WeForming RA, outlining its data flow and hierarchical structure.

In conclusion, this document presents the key takeaways from the initial stakeholder requirements gathering. It analyzes the implications for the Reference Architecture and establishes a clear roadmap for the subsequent project phases.

Target Audience

The target audience for this deliverable in the WeForming project encompasses a diverse range of stakeholders, including:

- Partners and Advisory Group within the WeForming project
- The European Commission (EC) and European Parliament (EP)
- Members of the European Union
- Other Horizon Europe projects, particularly those related to energy and smart building initiatives (for clustering activities)
- Organizations and experts engaged in the WeForming case studies

Other pertinent entities, both public and private, which may include associations representing stakeholders relevant to the project's scope and objectives.

2. User engagement, awareness, accessibility and co-creation

2.1. Identification of building users

The EU is a leading actor in promoting smart technologies within buildings and electricity infrastructure, paving the way for efficient energy use and sustainable living. The advantages of smart grids extend across the environment, the economy, and the society. However, transitioning to smart grids is a challenging and continuous process due to the diverse and interconnected technical, regulatory, political, economic and societal dimensions of the electricity sector (Verbong et al., 2013).

The societal aspect often receives less attention than the others, despite that the success of smart grid technologies leans on social acceptance within communities (Ponce et al., 2016). The end users of the buildings are often neglected from energy research and their awareness of smart grids was found to be low, posing a significant barrier to the implementation of the technology (Flavia et al., 2013; Ponce et al., 2016).

Since the final users of buildings are their tenants and visitors, public engagement is pivotal for transitioning to iGFBs and for building awareness of the new electricity infrastructure (Ponce et al., 2016). To achieve the acceptance of smart grids from their end users needs continuous communication and education on the new technologies (Bugden & Stedman, 2021; Verbong et al., 2013). These actions can help users overcome the barriers that they are facing, accept the changes that smart grids require, and consequently implement iGFBs successfully.

The project's focus lies on engaging building users and occupants of its demonstration projects with iGFB technologies. To achieve this engagement, the first step is identifying the end users of the demonstrations. The project comprises six pilots with commercial and residential buildings.

Commercial buildings

In the context of the WeForming pilots, the commercial buildings that are examined are shopping centres with numerous visitors that usually spend many hours on different activities (e.g., shopping, cinema, dining, etc.). Such building types have increased amounts of energy needs, so the implementation of smart grids will be highly beneficial. However, one challenge for transitioning to smart grids in such buildings types is that they involve many different stakeholders: building managers, administration officers, shop owners, shop employees, technicians and parking managers are among those who will manage and use the energy systems of the buildings, so their engagement is pivotal (Table 1). Technicians are similarly important stakeholders in a shopping centre because they manage the lighting, heating, cooling, water supply and electrical machines of the buildings. Finally, customers or visitors are the main end users of a mall. However, they will not be part of the first survey that we have launched as the perception of energy efficiency was found to be weak factor in choosing a shopping centre among visitors (Woods et al., 2016). However, because customers' needs often change, later in the project, a short survey that targets customers will be distributed to measure their knowledge and interest in choosing sustainable shopping malls.

Residential buildings

In residential buildings, the primary end users are homeowners who own residential property, renters, and tenants as well as service workers in waste management and recycling and emergency services (Figure 1). Other targeted end users include workers in parking areas, nursing home caretakers, school communities, office workers and guests who temporarily stay in the residential unit (Au-Yong et al., 2017).

FIGURE 1 COMMERCIAL AND RESIDENTIAL BUILDINGS END USERS

2.2. Engaging building users

The purpose of the survey (Appendix 1) is to provide insights into end users beliefs, knowledge, needs and wants regarding iGFBs so that we can then address them in workshops—our next step in terms of end-user engagement.

The survey is distributed to the demos, who share it with the users as mentioned in the previous section. The survey is hosted in the EUSurvey platform and a privacy statement for the personal data is provided to the respondents s at the beginning of the survey. It is translated into the languages of the pilot countries (English, Croatian, German, French, Spanish, Portuguese), so the definitions of smart grids, iGFBs and the terminology used will be understandable by the respondents without language limits. Additionally, we included demographic questions about the gender, age, education and occupation of the respondents so we can measure later on to what extent we achieved inclusivity.

At the beginning of the survey, definitions of smart grids and iGFBs are given to the respondents to ensure a clear understanding of the questionnaire's focus. The goal is to gather data from end users on their technical knowledge on smart grids, energy monitoring, and, finally, enquire about the barriers that could prevent them from using smart grid technologies. The survey questions are based on previous research (Bugden & Stedman, 2021; Flavia et al., 2013; Li et al., 2022; Luthra et al., 2014).

The first part of the questionnaire is about respondents' awareness on smart grids and iGFBs technologies (Ponce et al., 2016). The second part addresses energy use and user behaviour change. To achieve the long-term engagement of the users, behaviour change is important (Verbong et al., 2013). The acceptance of the iGFBs will be possible through incentives that will attract the end users to adopt the technologies and continuous communication so that building users will embed the new technologies in their lifestyle and overcome the barriers that prevent them from adopting the technologies. According to previous research, behaviour change can be induced through economic incentives, education on how to use smart grid technologies, and finally emotional incentives (Flavia et al., 2013; Verbong et al., 2013). To evaluate the respodents' predisposition towards behaviour change, we included different statements and questions, for instance, on monetary incentives (Benders et al., 2006).

Another factor that could prevent users from accepting smart grids is their privacy (Luthra et al., 2014). To measure the energy consumption of the users, data will be used and shared with energy actors that consumers cannot control. Finally, a possible barrier that we address in the survey, is the lack of interest in energy consumption and the perceived inconvenience of monitoring and managing energy usage, which may deter users from actively engaging with smart grid technologies.

2.2.1. Workshops

After the initial data gathering from the survey, end-users' engagement will be supported by multiple workshops that will happen during the project. In the workshops, the goal is to gather 20-40 users in each demo and discuss the technical information that they lack, and the barriers that they are facing that prevent them from accepting the smart grids. Additionally, the workshops aim to educate participants on smart grid technologies. We will conduct experimental scenarios to demonstrate how smart grids operate and showcase the use of smart technologies in various contexts (Ponce et al., 2016). The goal is to increase the acceptance and engagement of the participants.

By the end of the workshops, the participants will be more inclined to implement smart grid technologies and adopt new electricity behaviours. From the workshops, we will gather important information on what is further needed to support end users and ensure their smooth transition. In this way, new practices will be established to assist future projects.

A barrier that we must take into consideration, is the age of the population especially of the residential buildings. Elderly people are not used to adapting to new technologies as quickly as younger generations and it might be challenging to engage this group in the workshops.

2.3. Assessing user needs and desires

According to the data collected from the initial survey, the end users are interested to have control over their energy usage and would adopt new technologies to improve energy efficiency in their home/ workplaces, as Figure 2 shows.

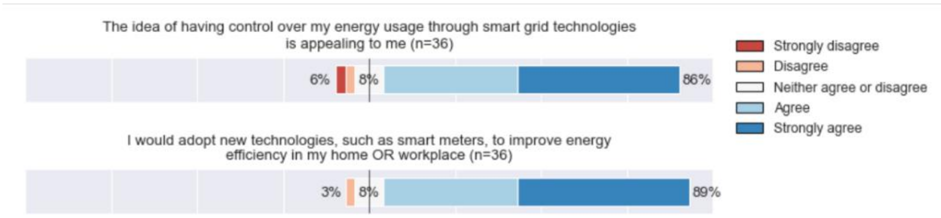

FIGURE 2 END USERS DESIRES

However, end users find it challenging to understand the smart grid technologies and how they work. This proves that the end users need more education so they will understand how these new technologies work and decide if they will adopt them (Figure 3).

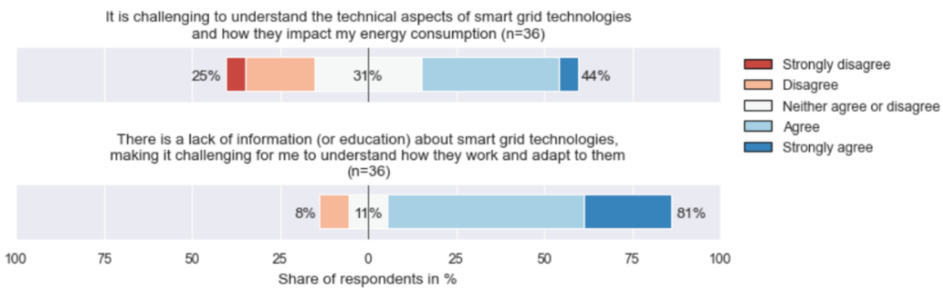

FIGURE 3 END USERS NEEDS

2.4. Summary of key findings

To achieve the adoption of iGFBs by society, it is important to involve end users through co-creation activities during the implementation period of the WeForming demos. Co-creation will play an important role in the project as it will ensure that final products will be aligned with the actual needs and preferences of the users. By engaging stakeholders early and continuously throughout the process, co-creation enhances the usability and acceptance of smart grids and other iGFB technologies.

Co-creation practices in this project involve collecting insights from surveys and discussing them with end users through interactive workshops. The workshops will bring together >50 users from each demo site to discuss and technical information they may lack and barriers they may face in adopting smart grid technologies. These sessions will not only educate participants through experimental scenarios but also foster a collaborative environment where users can provide feedback and share their experiences. This approach aims to increase the acceptance and engagement with smart grid technologies, ensuring that end users feel involved and informed about WeForming processes and technologies used.

The analysis of survey data will provide valuable insights into end users' beliefs and guide the development of targeted strategies to address users' technical knowledge gaps on smart grids and energy monitoring, as well as identify potential barriers preventing their adoption of smart grid technologies.

The sample of the survey consists of 36 respondents, with the majority being demo users from Spain. Among the participants, (69%) were men, and the dominant age groups were 25-34 (41%) and 35-44 (39%). The highest level of education is mainly a Master's degree (47%), while the main occupations are engineer (25%) and researcher (22%). Participants had already heard about smart grids from their workplaces (42%), and 53% were somewhat aware of the concept of IGFBs.

To measure the awareness of respondents on smart grids and IGFB technologies, the survey included multiple items. Respondents perceived the IGFB technologies as useful. They believe that through smart grids, carbon emissions will be lower since renewable energy resources can be used efficiently, leading to a greener and more sustainable energy future (Figure 4).

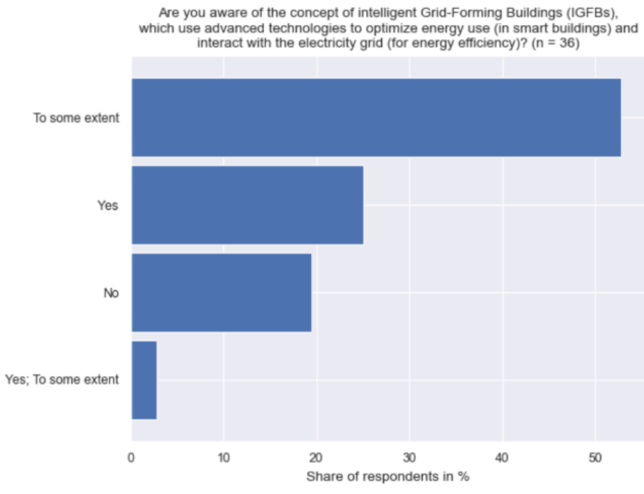

FIGURE 4 END USERS AWARENESS

Respondents' interest in smart grids is high. Results showed that participants are interested in controlling their energy usage and reducing their electricity consumption. The financial aspect is a significantly important incentive and would influence their decision to adopt smart grid technologies.

Possible barriers that would prevent users from adopting smart technologies are mainly the lack of information, implementation costs, and privacy concerns. Respondents regard smart grids as vulnerable to cyber-attacks, making them less secure than conventional energy systems (Figure 5).

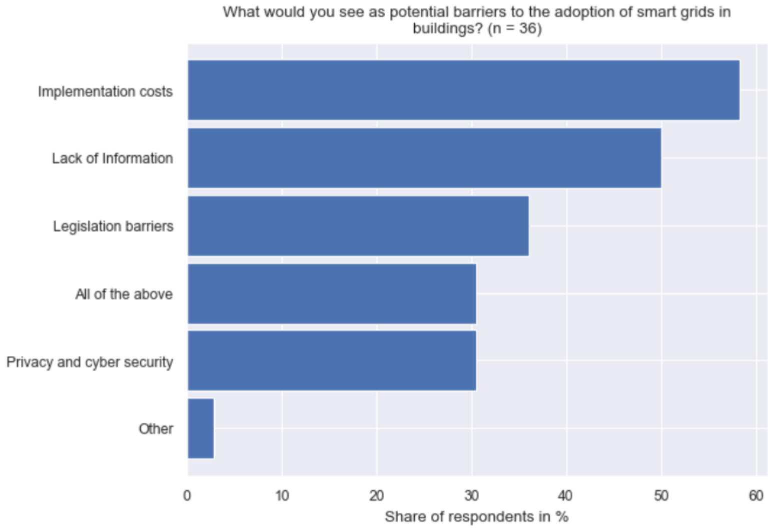

FIGURE 5 END USERS BARRIERS

Limitations

It is important to mention the limitations of the survey. The first limitation is the demographic concentration of respondents, predominantly from the Spanish demo, which may result in findings that do not represent the reality of end users' beliefs and needs. Additionally, the high educational level of respondents is a potential bias, as those with advanced degrees might have more awareness and understanding of smart grids compared to the general population. To overcome these limitations, the survey will be distributed again to the demos.

Conclusion

To conclude, the survey results highlight strong interest and perceived benefits in adopting smart grid technologies among users. However, addressing concerns related to information dissemination, costs, and security is crucial for successful implementation and widespread adoption.

3. Novel business models design for European energy-efficient and climate neutral building-to-grid integration

The chapter is organised in three subparts, focusing first on existing revenues opportunities for iGFBs and then proposing several novel business model designs for the single-use and multi-use buildings. The main objective of this chapter, which is aligned with the objective O8 (European Commission, 2023) of the Grant Agreement, is to unlock and promote innovative use cases and business models for intelligent, efficient and grid-interactive buildings in relevant sectors.

To this aim, it is important to understand the different products and services that can be generated by iGFBs from their integration into smart energy ecosystems for communities, mobility, commercial and industrial sectors to then, demonstrate innovative business models by mixing the contribution of different services, considering the regulatory aspects in each region.

Thus, the first section of this chapter analyses the existing revenue opportunities for iGFBs, drafting some regulatory specifics by country and analysing the main economic drivers for the implementation of these Business Models in iGFBs. Then, Potential future business models for single-use and multi-use buildings are analysed. They will be grouped in four categories: One Stop Shop, Product as a Service, Innovative Financial Schemes and New revenue models as depicted by FIGURE 6, and explained below:

a) One Stop Shop: This concept refers to a service provider that offers a range of energy-efficient renovation solutions, combining various services and products to streamline the process for consumers or businesses.

b) Product as a Service: Instead of traditional product ownership, customers pay for the use or access to a product as a service, often including ongoing maintenance, updates, and additional functionalities.

c) Innovative financial schemes: These schemes involve creative approaches to financing, such as home-based financing, on-bill financing, energy savings obligations, crowdfunding, and other methods that facilitate the funding of energy-efficient renovations and smart technologies.

d) New revenue models: These models encompass approaches like Pay-for-Performance or the provision of flexibility services to the grid, where building owners can benefit from increased rent due to improved smartness, and the enhancement of property value through labels and certification for non-residential buildings.

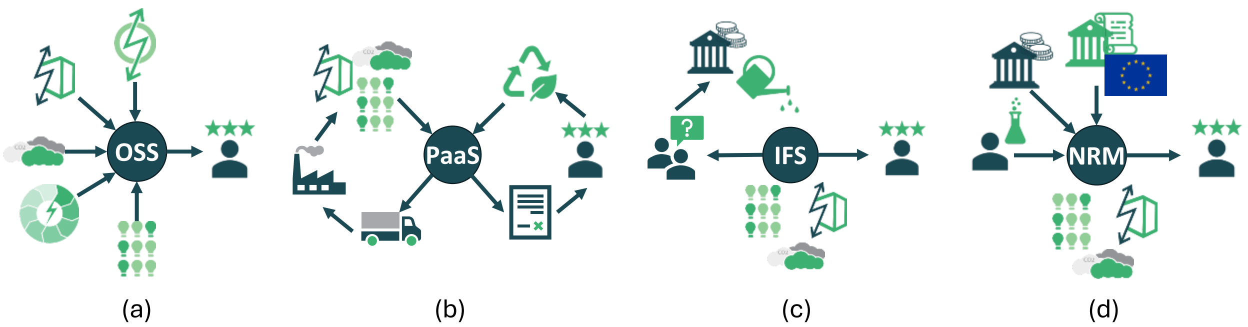

FIGURE 6. ILLUSTRATIONS OF THE DIFFERENT CATEGORIES FOR THE BUSINESS MODELS ANALYSED IN THIS CHAPTER. (A) ONE STOP SHOP, (B) PRODUCT AS A SERVICE, (C) INNOVATIVE FINANCIAL SCHEMES, AND (D) NEW REVENUE MODELS.

3.1. Existing revenues opportunities for iGFBs

3.1.1. Review of the existing opportunities across Europe

This section delves into the landscape of existing revenue opportunities within European energy-efficient and climate-neutral building-to-grid integration. It explores various models and initiatives across Spain, Greece, Luxembourg, Portugal, Belgium, Germany, Ireland, and Croatia. These include existing opportunities for Citizens Communities, Mobility Initiatives, Commercial Buildings and Industry. This section illustrates what is the state of development of new business models by showing the current landscape for each type of sector and country.

Existing Revenue Opportunities for Communities

Spain has one of the largest constellations of renewable energy communities in the EU. Renewable Energy Communities (RECs) were legally defined for the first time with the Royal Decree 23/2020 (Spanish Government, 2020). According to (European Commision, 2024), there are in 37 registered communities in Spain.

TABLE 1. ENERGY COMMUNITIES IN SPAIN

Energy Communities in Spain:	
Enverde[1]	**Voltregà Energia, SCCL** [2]
Agrícola Falset-Marçà i S.C. AFALMA SCCL	**SEB EN TRANSICIó** [3]
Masterpiece – UMU	**Tarsos** [4]
Comptem - Grupo ENERCOOP [5]	**Balenyà Sostenible SCCL** [6]
Colmena [7]	**Som Comunitat Energètica del Barcelonès SCCL** [8]
Ekogella [9]	**CED SABARCA AREA8, SL** [10]
Piztu Kooperatiba Sozietatea [11]	**Agrícola Falset-Marçà i S.C. AFALMA SCCL** [12]
Ixotzen Koop. S. [13]	**Associació Comunitat Energética de Forcall**
Elorrioko Energia berriztagarrien komunitatea, KOOP. S "argiñola" [14]	**Comunidad Energética Local de Alpuente**
Kemendi	**Sapiens Energia** [15]
Energia del Pallars JIUSSà, SCCL [16]	**Associació Comunitat Energètica Racó de Mar**
Energia Santjoanina [17]	**COENSOMA**

[1] www.energiaenverde.com
[2] voltregaenergia.cat
[3] sebentransicio.cat
[4] www.tarsos.cat
[5] www.grupoenercoop.es/conocecomptem
[6] www.balenyasostenible.cat
[7] www.electricadealginet.com
[8] somcebarcelones.cat
[9] www.ispaster.net/eu-ES/Orriak/default.aspx
[10] www.area8.cat
[11] https://piztu.eus
[12] www.etim.cat
[13] www.facebook.com/ixotzen
[14] https://www.argiñola.eus
[15] www.sapiensenergia.es
[16] energiajussa.cat
[17] www.energiasantjoanina.cat

Comunitat Energètica Montolivet [18]	**CEL Castellar-L'Oliveral** [19]
CEL de Mieres [20]	**CE Sierra**
SOM Energia, SCCL [21]	**Ecotxe** [22]
Alpens Energia SCCL [23]	**SOM SERVEIS ENERGèTICS S.COOP** [24]
PescaEnergia [25]	**Energía Bonita** [26]

An interesting Citizen Energy Community (CEC) with more than 85,000 members, founded in 2010 is Som Energia. The cooperative started by purchasing local renewable energy from existing RES to supply its members with affordable electricity prices. In the meantime, the cooperative has deployed its own renewable production projects within its local groups, with the goal of reaching of 100% of renewable energy supply to its members. The members are manly households, Small to Medium Enterprises (SMEs) and other renewable energy communities. The portfolio of Som Energia is mainly based in photovoltaic technology, biogas and hydropower. A large share of the PV capacity is installed in building, privileging the self-consumption.

In Greece the energy community legal form is limited to cooperatives. The law distinguishes two types of energy communities: non-profit and for-profit cooperatives. RECs can produce, distribute, and supply renewable energy from installations of up to 1 MW, and the activities can include (Dorian F, 2020):

- distribution of electricity,
- natural gas heating/cooling within the region,
- demand management to reduce the final use of electricity,
- representation of producers and consumers in the electricity market,
- network development,
- management and exploitation of alternative fuel infrastructure,
- installation and operation of desalination plants using renewable energy, and
- provision of energy services.

Until the end of January 2024, there were identified seven officially registered energy communities across Greece (European Commision, 2024):

TABLE 2. ENERGY COMMUNITIES IN GREECE

Energy Communities in Greece	
Collective Energy [27]	**CommonEn** [28]
Hyperion [29]	**Energy Community Dim. Ypsilantis**

[18] : www.instagram.com/cemontolivet
[19] celcastellaroliveral.org
[20] www.celdemieres.cat
[21] www.somenergia.coop
[22] www.ecotxe.coop
[23] www.alpensenergia.cat
[24] www.somserveisenergetics.coop
[25] www.pescaenergia.cat
[26] www.energiabonita.coop
[27] https://coen.coop/
[28] https://www.commonen.gr
[29] https://hyperion-community.gr

Solarity Renewable Energy Community [30]	**Energy Cooperative WEnCoop** [31]
Energy Community of Karditsa (ESEK) [32]	

In Luxembourg RECs, have the right to access all energy markets to sell their excess electricity directly or through aggregation (Chambre of Deputies, 2023). RECs are authorized to delegate the organization of electricity sharing to a service provider. The excess of the renewable electricity produced among the communities' members can be fed into the grid through the energy suppliers, directly to the DSO through renewable power purchase agreements, or via aggregation by participating in a community Virtual Power Plants (cVPP), increasing the value to market by increasing the volumes for sale. Larger aggregation pools can act in this case as Balancing Responsible Party.

At beginning of 2024, there were identified seven energy communities, recently created from existing citizen-led energy cooperatives (European Commision, 2024). Most of these communities are based on PV production installed in residential buildings, but also in SME buildings, in some cases still having shares of installed capacity under active Feed in Tariff (FiT) contracts, or just for shared self-consumption and injecting the surpluses to the grid under PPAs. These are:

TABLE 3. ENERGY COMMUNITIES IN LUXEMBOURG

Energy Communities in Luxembourg	
GREENERGY FEELEN-MäERZEG [33]	**ENERCOOP SYRDALL S.C.** [34]
REGIONAL ENERGIE COOPERATIVE – LEADER LëTZEBUERG WEST [35]	**TM ENERCOOP S.C.** [36]
ENERCOOP UELZECHTDALL [37]	**ENERGIEKOOPERATIV KANTON REMICH** [38]
EQUIENERCOOP [39]	

In Portugal RECs were initially defined with the Decree 162/2019 (Portuguese Goverment, 2019), which approved the legal regime applicable to self-consumption of renewable energy for the first time in the country. Later replaced by the Decree 15/2022 (Portuguese Government, 2022) on the organisation and operation of the National Electrical System both RECs and CECs, possible configurations and limitations were fully defined as the role of the aggregators. Despite the favourable regulatory framework, Portugal only has 4 operating energy communities:

TABLE 4. ENERGY COMMUNITIES IN PORTUGAL

Energy Communities in Portugal	
C-COOP – Cooperativa para a sustentabilidade da Ilha da Culatra [40]	**Cooperativa Coopérnico** [41]
Telheira renewable energy community [42]	**Cooperativa A LORD** [43]

[30] https://solarity.coop
[31] https://wencoop.gr
[32] https://www.esek.gr
[33] www.greenergy.lu
[34] www.facebook.com/enercoopsyrdall
[35] www.ecoop-west.l
[36] tmernercoop.lu
[37] ecud.lu
[38] www.ekr.lu
[39] www.equienercoop.lu
[40] www.culatra2030.pt
[41] www.coopernico.org
[42] vivertelheiras.pt/certelheiras
[43] www.alord.pt

These are based in different business models, ranging from the simple *sharing of the excess of self-production* units among the member members (C-COOP) to a more complex services structure, as it is the case of Cooperativa Coopérnico. As one of the largest Citizen energy communities in the country, Cooperativa Coopérnico, accounts already with more than 5,160 members, mostly households but also SMESs, local authorities, government agencies, schools and universities, NGOs and associations, private energy companies or utilities, public energy companies, institutional investors, commercial banks, state banks, and other energy communities. The REC offer a wide range of services for the development of distributed infrastructure for renewable production, namely PV installed on buildings. Acting as an investment aggregator, promotes collective investment pools among members, and also open to external investors for the development of PV generation installations.

Cooperativa Coopérnico recently became an energy supplier in partnership contract with EZURIMBOL – COMÉRCIO DE ELETRICIDADE, LDA.[44], a Portuguese aggregator, which ensures access to the networks and the relationship with the operators of the national electrical system, as well as the purchase and delivery of energy to the grid.

Apart from activities as financial advice, training and education and technology development for smart metering, Cooperativa Coopérnico, also promotes collective refurbishment of buildings and energy efficiency advisory services.

Portugal has made strides in defining RECs and CECs with legal frameworks that support self-consumption of renewable energy and outline the operation of these communities. Despite a favourable regulatory environment, Portugal has a relatively small number of operating energy communities, including C-COOP, Telheira Renewable Energy Community, Cooperativa Coopérnico, and Cooperativa A LORD. These communities vary regarding business models, from simple sharing of self-production units to more complex services structures, with Cooperativa Coopérnico being one of the largest, offering a wide range of services and acting as an investment aggregator for renewable energy projects.

In the case of Belgium, the first local energy community was established in September 2022 in the city of Mechelen. 70 homes and 15 apartments participate in energy sharing from 729 solar panels installed on their rooftops. The DSO in the city of Mechelen provided reduced grid fees to make peer-to-peer (P2P) trading more attractive (Bonfert, 2024).The lists of energy communities and cooperatives are listed below:

TABLE 5. ENERGY COMMUNITIES IN BELGIUM

Energy Communities in Belgium	
Ampère CV[45]	**Klimaan CVSO**[46]
BeauVent CVBA[47]	**Pajopower CVBA**[48]
BronsGroen CVBA-so[49]	**Megawattpuur**[50]
Brupower CV[51]	**Navitas CVSO**[52]

[44] ezurimbol.pt
[45] https://www.amperecv.be/.
[46] https://coop.klimaan.be/
[47] https://www.beauvent.be/
[48] https://www.pajopower.be/
[49] https://www.bronsgroen.be/
[50] https://megawattpuur.be/
[51] https://coop.brupower.be/
[52] https://www.navitasenergie.be/

Campina Energie CVBA[53]	**Noordlicht**[54]
CoopStroom CVBA	**Stroomvloed CVBA**[55]
Denderstroom CVBA[56]	**Vlaskracht CVBA**[57]
Druifkracht CV[58]	**Volterra CVBA**[59]
ECoOB CVBA[60]	**ZonneWind CVBA**[61]
EnerGent CVBA[62]	**ZuidtrAnt CVBA-so**[63]
Ecopower CVBA[64]	

In all these cooperatives, members invest in renewable energy projects allowing them to achieve lower electricity costs and additionally receive a profit share from the capital contribution. Some of them offer additional benefits, e.g. BeauVent CVBA members can enjoy tickets at a 50 % discount for a local aquapark, buy pellets and briquettes at an affordable price, receive an annual dividend between 3.25 and 6%, or use an electric shared car. With these initiatives, RECs can offer very competitive pricing for energy, in the case of Ixelles, sharing PV panels among two schools reduced the price of energy from 0.30 €/kWh (typical retail market) to 0.18 €/kWh. Other initiatives in this country, involves the Interconnect and Bright projects, which are focused on P2P energy sharing and creating dynamic tariffs in energy communities to increase energy awareness and involve citizens in their energy communities[65][66].

In Germany, more than 900 renewable energy cooperatives with more than 200,000 members are active (European Commission, 2024). Collective self-consumption in Germany is known as “Mieterstrommodell” (tenant electricity) which enables selling excess electricity from locally produced renewable energy source to the tenants in the direct proximity. Members enrolled in these types of programs do not need to pay network fee, grid-side surcharges (such as KWKG levy which supports the generation of electricity from combined heat and power plants – in 2024 set at 0.275 ct/kWh), electricity tax and concession fee (Bundesnetzagentur, 2024), (Bundesnetzagentur, 2024). Electricity prices may not exceed 90% of the basic supply tariff applicable in the respective network area. Hager Wissen and Vattenfall (Hager, 2024), examples of tenant electricity options, has subsidized and non- subsidized offers. The subsidized variant is limited only to PV generation which must be delivered to the consumers in the building where it is located or nearby district. The amount of the tenant electricity surcharge is legally defined at 2.67 ct/kWh for systems up to 10 kW, 2.48 ct/kWh for systems up to 40 kW, and 1.67 ct/kWh for systems up to 1 MW. In non-subsidized version, electricity can be produced from PV and Combined Heat and Power (CHP) systems, while prices are not subject to any legal regulations.

Collective self-consumption in Ireland does not exist as 97% of residential buildings are single dwellings (Compile, 2020). Sustainable Energy Communities is a movement in Ireland focused on the producing energy from renewable energy sources on the local level from the citizens’ initiatives (Greenoffaly, 2021).

[53] https://www.campinaenergie.be/
[54] https://noordlicht.be/
[55] https://stroomvloed.be/
[56] https://denderstroom.be/
[57] https://www.vlaskracht.be/
[58] https://www.druifkracht.be/
[59] https://volterra.be/
[60] https://www.ecoob.be/
[61] https://zonnewind.org/
[62] https://energent.be/
[63] https://www.zuidtrant.be/
[64] https://www.ecopower.be/
[65] https://www.brightproject.eu/belgium/.
[66] https://interconnectproject.eu/pilots/belgium-2/

Community Power[67] is the first community owned renewable electricity utility company which offers lower electricity rates compared to other electricity suppliers.

Lastly, Croatian regulation allows collective-self consumption for multi-apartment buildings and formation of energy communities. However, strict rules, complicated and expensive administrative procedure for establishing and operation of energy communities inhibit the interest of citizens to join or start such projects. Only one energy community exists in Croatia - My Energy Community[68], recently founded and still not in operation. Projects of collective self-consumption are still not realized in practice. There were several crowdfunding projects organized for PV installation, such as Compile project which resulted in PV installation on a library and urban technology development centre with office buildings in the city of Križevci[69].

Existing Revenue Opportunities for Mobility Initiatives

Within this category, a noteworthy development was made in Belgium in the city of Mechelen, where a sustainable mobility hub in parking garage buildings that uses PV, battery storage, and electric vehicle charging infrastructure was deployed. The mobility hub is run by the municipality in collaboration with private housing company and includes P2P energy sharing between two businesses renting space in the building (Interreg - North Sea Region, 2023). 20 AC charging points, 4 DC, and 2 Vehicle to Grid (V2G) charging points were installed to maximize self-consumption, smart steering, and sharing of surplus solar energy between charging infrastructure operator, supermarket, and offices on 2 floors.

In the case of Germany, The Federal Ministry for Economic Affairs and Energy is actively funding research and development (R&D) initiatives in electric mobility, covering various aspects such as drive technology, battery research, grid integration, and smart charging infrastructure. These initiatives aim to support the transition towards electric mobility, strengthen industrial competitiveness, and contribute to energy and climate policy goals. The ministry's funding programs, including ELECTRIC POWER II, focus on advancing key technologies, standardization, and the development of charging infrastructure, with a particular emphasis on collaboration between industries and research institutions to drive innovation and reduce production costs (Federal Ministry for Economic Affairs and Climate Action, 2020).

In Spain, most of the novel business models for mobility schemes are linked to RECs, since they allow very attractive prices for charging, the Minister for Transport, Mobility and the Urban Agenda, has deployed the Sustainable Mobility Law (Ministerio de Transportes y Movilidad Sostenible, 2022) aiming to prioritize citizens' access to essential services and employment, address climate challenges, embrace digitalization in transportation, and ensure public investments align with societal needs, fostering cleaner, inclusive, and innovative mobility solutions. Since then, several platforms for Sustainable Mobility have arisen. Noteworthy, the association “Empresas por la Movilidad Sostenible[70]” has achieved to gather multiple private-sector companies for the development of these initiatives. Besides, companies such as “Blablacar” and “Amovens” have achieved to successfully integrate carpooling sharing among individuals for a service fee, registering a net income of 253M€, and 2.6M€, respectively.

Another business model in the context of sustainable transportation, specifically micromobility, including shared mobility services, ride-hailing, scooter sharing, bike sharing, and car sharing. Shared mobility services, such as scooter and bike sharing, have experienced significant growth, with the shared mobility sector in Spain projected to reach a turnover of over €1,400 million by 2025. Ride-hailing services offer convenient transportation options, while scooter sharing is highlighted for its affordability and perceived safety. The investment in the micromobility sector in Catalonia alone has reached €222 million over the past five years, resulting in the creation of 372 jobs. Car sharing provides flexibility for users who require

[67] https://communitypower.ie

[68] https://www.myenergycommunity.eu/

[69] https://main.compile-project.eu/sites/pilot-site-krizevci/

[70] https://www.movilidadsostenible.com.es/listado-miembros/

occasional access to a vehicle. These business models are supported by advancements in technology, including IoT sensors for fleet management, blockchain for secure transactions, big data and AI for data analysis, and connectivity for seamless user experiences. Additionally, investments in micromobility companies, both locally and internationally, highlight the growing interest and potential for expansion in this sector (Generalitat de Catalunya, 2022).

Another interesting initiative promoted by the University of Murcia as part of the MASTERPIECE HE project[71], leverages a meshed medium-voltage network to optimise the energy flows within the buildings and the e-mobility infrastructure among different buildings. Several business models have been tested, such as the provision of services: e-mobility communities, flexibility service to markets and the DSO, demand side management, energy advice and energy efficiency services.

Existing Revenue Opportunities for Commercial Initiatives

Creos, the Luxembourgish TSO, jointly with the Luxembourg Institute of Science and Technology and the University of Luxembourg's Interdisciplinary Centre for Security, Reliability and Trust is conducting a project entitled "Flexibility potentials and user behaviour analysis" (FlexBeAn)[72] , which aims to study and model the flexibility potential of electricity consumers, focusing households, the industrial sector, SMEs, and e-mobility operators sector to better understand the behaviour of the different stakeholders and their engagement level and willingness to participate potential remunerated flexibility demand response programs based on the evolution of energy markets over the next few years.

Hotels in Hamburg and Norderstedt participate in Interconnect project to manage overload and underload scenarios using bi-directional communication from grid to device level via an energy management system, manage flexibilities to provide grid services and to optimize energy costs.

Existing Revenue Opportunities for Industrial Sector

Regarding Industrial initiatives, they mostly fall in two categories: Aggregation or Provision of Ancillary Services.

Aggregation

Since the liberalization of the Electric Energy trading market in the European Union, 44 renewable energy and capacity aggregators have been registered in Portugal: (Direção-Geral de Energia e Geologia, 2024), attracting some foreigner companies mainly from the Spanish market due to the business attractiveness. These companies create economic and operational benefits on behalf of large group of domestic consumers, businesses or organisations leveraging their collective buying or selling power.

E-Redes, the Portuguese DSO, launched a demand response pilot project, FIRMe – "Flexibility Integrated into Market Regime" (E-Redes, 2023), in September of 2023 for remunerate households for load flexibility through flexibility services auctions. Consumers can participate individually or collectively with a minimum offer of 10 kW. Remunerations, with fixed compensations, range from 400 to 800 euros per megawatt (MW) per year, and variable payments ranging from 15 to 1000 €/MWh. The objective of the project is to adapt the system to the flexibility services' provisioning requirements and test the market by raising awareness among potential flexibility service providers (FSPs) and engaged them to participate flexible local markets.

Next Kraftwerke is an aggregator in Belgium and offers consumers and producers to become a part of a virtual power plant Next Pool. Flexicity is an aggregator in Belgium which optimizes the flexibility of consumers and producers. Buildings can provide mFRR if they can modulate their electric power within

[71] https://masterpiece-horizon.eu
[72] https://www.creos-net.lu/de/creos-luxembourg/projekte/flexbean/flexbean-project.html

15 minutes a few times in a year. A flexible asset always available could have generated up to 43,800 €/MW in mFRR of availability remuneration according to market price (Veolia, 2022).

Two aggregators operate in Croatia, KOER[73] and Nanoenergies[74]. KOER aggregates producers, consumers and energy storage facilities with the requirement of minimum 100 kW decrease in the consumption.

Providing flexibility from buildings in Croatia was investigated in the project 3smart (Interreg, 2019), while PV integration on family houses and small family buildings was studied on the island Krk withing the Fresco project[75].

Recently, in Q3 of 2022, Sympower[76] has become the first independent aggregator in Greece's balancing markets approved by the Greek TSO. Acounting with 37MW of capacity for the Greece's balancing markets, Sympower is aggregating energy flexibility of industry facilities across the country that is offered in the balancing markets creating new revenue streams for those businesses. The aggregation in this case is mainly flexibility based in demand response but also in storage systems. Aggregated pool is composed by multiple industries such as: metal production, pulp and paper mills, battery energy storage systems, e-mobility operators, water treatment facilities, and food processing industries.

The aggregator role in Luxembourg is foreseen in the recently amended law relating to the organization of the electricity market N288/09 June 2023 (Chambre of Deputies, 2023), where the aggregation activity is defined as a function of combining multiple loads of consumption or production of electricity, with the objective of selling, buying or auctioning on the wholesale market. The aggregation activity should not be performed by customer's electricity supplier, guaranteeing maximum independence from the customer's supplier. In the scope of the new legal framework, it was founded in the first community Virtual Power plant organization, e-Community[77]. A pioneer cooperative open to the whole of civil society, formally certified as a "Société d'impact Sociétal", which aims to offer an aggregation platform of energy assets on the national territory, enabling the sharing of renewable electricity produced between energy communities and other individual active costumers, such as prosumers and renewable energy producers at the private and public level. As an aggregation entity, the e-Community mission is to develop and conduct energy community governance, energy trading management, and develop new renewable energy production projects with the participation of citizens, other energy cooperatives, public actors, non-profit associations, foundations, and corporations. The e-Community management of the renewable energy traded among the community members lands on the maximization of local self-consumption through the balance of tailored dynamic tariffs application and the participation in the energy wholesale market with the community residual energy.

Provision of Ancillary Services

Buildings in Germany can achieve additional cost savings or increase their income by providing primary, secondary, and tertiary control. These types of services are usually provided by big factory buildings capable of reducing their load for the required amount of flexibility. Moreover, citizen-related initiatives such as cooperatives are significant in Germany. Collective self-consumption or in Germany called tenant electricity ("Mieterstrommodell") involves energy sharing on the local level which brings several benefits to involved participants. Several projects in Germany tested different flexibility options and possibilities of p2p trading on demo sites across the county. The list of aggregators, the type of service they provide, and possible providers are shown in **Table 6.** (Stede, 2020):

[73] https://www.koer.com/

[74] https://nanoenergies.hr/

[75] https://www.fresco-project.eu/krk-island/

[76] https://sympower.net/sympower-goes-live-in-greeces-balancing-markets

[77] https://e-community.lu/

TABLE 6. AGGREGATORS IN GERMANY

Aggregator	Providers	Primary control	Secondary control	Tertiary control	Switchable loads
Axpo Deutschland		+	+	+	
BalancePower	**Food industry**		+	+	
BayWa r.e. CLENS	**Primary industry, food industry**		+	+	
energy2market		+	+	+	+
Entelios	**Primary industry, food industry, aerospace**	+	+	+	+
GETEC Energie	**Energy intensive industry**	+	+	+	
MVV Energie			+	+	
natGAS	**Primary industry, food industry, automotive**		+	+	
Next Kraftwerke	**Different industries**	+	+	+	+
REstore	**Primary industry, food industry**	+	+	+	+

In the electricity market, the production mix of RESs of the Greek DAM, are mainly solar and wind power plants represented by RES independent aggregator (Makrygiorgou, 2023). However, RES participation in the Balancing Market, has been hampered by the regulation framework. FiT RES traditionally did not have balancing responsibility, imbalances were credited/debited to Greek RES operator, DAPEEP. Nowadays Feed-in-premium (FiP) RES currently have full balancing responsibility, and RES that have terminated are subject to balancing responsibility and balancing prices opening the new market opportunities for aggregation players. Storage participation was limited only to hydro storage units for provisioning only mFRR services due to their inflexible on–off operation. The latest market reform foreseen battery storage systems that can provide not only mFRR but also aFRR, FCR, and voltage control services (European Commision, 2021). Even, Project Interflex[78] tested ancillary services provision by households connected to the low voltage network in the city of Lüneburg.

Overview of the Existing Revenue Opportunities for iGFBs

The review of existing opportunities for energy-efficient and climate-neutral building-to-grid integration across Europe reveals a diverse landscape of business models and initiatives tailored to specific regional and sectoral contexts. Each country examined—Spain, Greece, Luxembourg, Portugal, Belgium, Germany, Ireland, and Croatia—has leveraged unique regulatory frameworks and market conditions to foster the growth of RECs, CECs, and innovative mobility and industrial projects.

Spain and Germany demonstrate mature markets with substantial participation from numerous energy communities and cooperatives, reflecting advanced regulatory support and significant citizen engagement. Greece and Portugal have established foundational legal structures to support RECs and CECs, though the number of active communities remains modest, suggesting room for growth and greater public awareness. Luxembourg and Belgium illustrate innovative approaches to market participation and aggregation, enhancing the value of renewable energy through cVPP and other cooperative models.

[78] https://interflex-h2020.com

Mobility initiatives across the region, particularly in Belgium, Germany, and Spain, highlight the integration of renewable energy with electric vehicle infrastructure, demonstrating a shift towards sustainable urban mobility solutions. Similarly, commercial and industrial sectors show promising developments in flexibility management and ancillary service provision, with various pilot projects and aggregators playing a critical role in optimizing energy use and market participation, but efforts are needed towards a full development as for the case of the energy communities.

3.1.2. Regulatory assessment

Belgium

In Belgium, the energy sector's regulatory environment is fragmented among its three regions: Flanders, Wallonia, and Brussels, each with distinct energy regimes. Flanders leads with six suppliers offering dynamic energy contracts for both energy offtake and injection, while Brussels lacks such offerings. The Flemish region recently reduced support for solar panels and batteries and switched to a capacity-based grid tariff model, ending net metering. Wallonia has transitioned from a publicly funded prosumer fee to a proportional payment system for residential solar, with distinct mechanisms for new installations post-2024. Belgium's national legal framework lacks cohesion, hindering efficient iGFB operation. The European Union Agency for the Cooperation of Energy Regulators (ACER) study of December 2023 highlights the need for a unified legal framework, accelerated smart meter rollout, and more flexible capacity mechanisms to enhance the retail market and manage taxes and levies more effectively (European Unition Agency for the Cooperation of Energy Regulators (ACER), 2023). Differences among Belgium's regions exist in this sense:

- **Flanders**: This region has developed detailed regulations that facilitate the integration of energy aggregators and VPPs into the local grid, focusing on renewable energy generation and consumption.
- **Wallonia**: Similar to Flanders, Wallonia has also implemented supportive measures for VPPs and energy aggregators, with specific incentives for renewable energy projects.
- **Brussels**: Brussels region has focused on urban energy management, adapting the EU's frameworks to suit the high-density living areas and integrating VPPs into the city's energy infrastructure.

Croatia

Croatia's Energy Development Strategy targets a significant increase in production from distributed renewables, aiming for over 35% renewable generation by 2030. Relevant regulatory categories include "active consumer", "collective active consumer", "citizen energy community", and "renewable energy community". However, implementation is slow due to insufficient incentives and administrative hurdles. Recent changes in the electricity market law have reduced barriers, but challenges persist, such as a lack of a flexibility market for end-users on the distribution network and capped energy prices that disincentivize renewable production. ACER recommends comprehensive legal framework development, smart meter deployment enhancement, and capacity mechanism revision.

In Croatia, the regulation surrounding VPPs, and aggregators is still developing, reflecting the country's gradual integration of these innovative energy management systems into its national framework. Croatia has begun to recognize the potential of VPPs, particularly in facilitating the market access for prosumers—consumers who also produce energy, typically via solar panels. This is part of a broader effort to decentralize energy production and increase the use of renewable sources.

The country's first virtual power plant, established by KOER, illustrates this move towards a more integrated and flexible energy system. This VPP aggregates various small-scale energy producers to manage electricity generation and consumption more efficiently across the grid. This approach not only helps balance production with demand but also offers ancillary services like voltage regulation directly to the Croatian Transmission System Operator (HOPS), which is crucial for maintaining grid stability.

Despite these advances, the cost of integrating technologies for small-scale producers remains high, posing a barrier to broader participation. However, the legal and regulatory framework does support the aggregation of these small energy producers, allowing them to contribute effectively to the grid's needs.

Germany

Germany's regulatory progress on enabling iGFBs has initially been slow due to limited smart meter rollout and a lack of relevant tariff models. Recent legislative changes aim to accelerate smart meter deployment and define rules for flexible loads, especially for emergency curtailment schemes. These include mandatory participation of devices like EV chargers and heat pumps in demand reduction and incentivize grid-interactive home energy management systems. Germany also faces regulatory challenges in developing energy communities and is working on new rules for energy storage and bi-directional charging. ACER's recommendations include establishing a legal framework for new entrants, speeding up smart meter penetration, and improving retail market competition.

In Germany, the regulatory framework specific to the generation, distribution, and commercialization of renewable energy is primarily governed by:

- **Erneuerbare-Energien-Gesetz (EEG)**: This act facilitates the development of renewable energy by mandating the increased share of renewables in the energy mix and outlining specific conditions for the marketing and remuneration of electricity from renewable sources. (Bundesregierung, 2023)
- **Energiewirtschaftsgesetz (EnWG)**: This energy act covers general regulations for the energy sector, including the access and connection to electricity networks, which are crucial for the operation of VPPs (Bundesministerium der Justiz, 2005).

Luxembourg

In Luxembourg, more than 90% of households already have smart meters. A 2020 law harmonized policies on self-consumption and renewable energy communities, allowing individual renewable energy producers to sell or store excess electricity. Collective self-consumption is facilitated by contracts with the DSO, and subsidies encourage individual self-consumption installations. However, grid capacity issues and public resistance to expansion are challenges. ACER recommends focusing on legal frameworks for new entrants, smart meter rollout, capacity mechanism requirements, and retail market competition.

Portugal

Portugal's evolving regulatory landscape for iGFBs emphasizes grid integration and collective self-consumption. The 2019 Decree-Law introduces a surplus energy remuneration model and refines grid interconnection standards. Challenges persist in regulatory approval processes and the legal frameworks for Renewable Energy Communities. The IEA recommends fostering competitive markets, incentivizing flexibility, and addressing technical integration and cybersecurity concerns.

Regulatory specifics for the energy market in Portugal promote the development of RECs and CECs, along with the role of aggregators. Key frameworks include:

- **Initial Legal Framework:** The concept of RECs was initially introduced in Portugal through Decree 162/2019, establishing the legal regime for self-consumption of renewable energy. This framework was later refined and replaced by Decree 15/2022, which detailed the organization and operation of the National Electrical System, fully defining the configurations, limitations, and the role of aggregators for both RECs and CECs.
- **Operational Energy Communities:** Despite a supportive regulatory environment, Portugal has still today only a few operating energy communities, including C-COOP, Telheira Renewable Energy Community, Cooperativa Coopérnico, and Cooperativa A LORD. These communities use diverse business models, from simple sharing of excess self-production among members, to complex

service structures like those offered by Cooperativa Coopérnico, which acts as an investment aggregator for renewable energy projects.

Spain

Spain's energy policy reforms aim for climate neutrality by 2050, with significant renewable energy development and energy efficiency improvements. The decentralized governance requires coordination for effective policy implementation. Spain leads in energy communities, allowing collective self-consumption without forming legal entities. Technical challenges include integrating renewable energy into the grid and modernizing infrastructure, with smart meter implementation nearly complete, and a focus on substation upgrades. ACER advises developing a comprehensive legal framework for new market participants, addressing capacity mechanism requirements, and stimulating retail market competition.

Overview of the Regulatory Assessment

The regulatory landscape for the energy sector in Europe varies significantly by country, affecting the development and integration of iGFBs. To derive use cases adapted to the regulations and boundary conditions of different countries, we must understand each region's specific regulatory environment and identify the most suitable business models accordingly.

In Belgium, the fragmented regulatory environment across Flanders, Wallonia, and Brussels presents challenges for efficient iGFB operations. Flanders offers dynamic energy contracts and has transitioned to a capacity-based grid tariff model, whereas Wallonia has implemented proportional payments for residential solar. The national framework's lack of cohesion necessitates a unified legal framework and accelerated smart meter rollout, as highlighted by ACER.

Croatia aims for significant renewable generation increases by 2030 but faces slow implementation of incentives and administrative burdens. Recent legislative changes have reduced barriers, yet challenges like the absence of a flexibility market and capped energy prices persist. The establishment of Croatia's first VPP by KOER shows potential, though high integration costs remain a barrier.

Germany's slow regulatory progress due to limited smart meter deployment and inadequate tariff models has recently seen improvements with legislative efforts to define rules for flexible loads and support energy communities. ACER recommends a comprehensive legal framework for new entrants, faster smart meter deployment, and enhanced retail market competition.

Luxembourg has advanced significantly with over 90% of households equipped with smart meters and a 2020 law harmonizing policies on self-consumption and renewable energy communities. However, grid capacity issues and public resistance pose challenges. ACER suggests focusing on legal frameworks for new entrants, smart meter rollout, capacity mechanisms, and retail market competition.

Portugal's regulatory framework supports grid integration and collective self-consumption, but challenges persist in regulatory approval processes and legal frameworks for RECs. Despite few operating energy communities, Portugal's supportive environment suggests potential for growth with further regulatory improvements.

Spain aims for climate neutrality by 2050 with a focus on renewable energy and efficiency. Decentralized governance and nearly complete smart meter implementation highlight its progress. ACER advises developing a comprehensive legal framework, addressing capacity mechanisms, and stimulating retail market competition to support this transition.

These regulatory assessments highlight the need for tailored use cases that align with local requirements and maximize potential success. The following business models for single-use and multi-use iGFBs will be as generalist as possible with the objective of adapt them to the regulatory specifics of each country.

3.2. Potential future business models for single-use iGFBs

Single-use iGFBs in the WeForming project are buildings designed with a specialized function or capability that enhances the building's energy profile and contributes to grid stability. **The "single-use" term refers to the primary function around which the building's energy strategy is designed.** This could be a particular energy-saving feature, a unique energy storage system, or a specialized demand response capability. The focus on "unique functionality" means that the building offers a specific benefit to the energy grid, like peak load shaving or providing emergency power during outages.

This section will analyse the potential future business model for single-use iGFBs. First analysing the single-use core functionality of iGFBs, then identifying potential stakeholders per functionality and providing different business models following these schemes: One Stop Shop Concept, Product as a Service (PaaS), Innovative Financing Schemes and New Revenue Models.

These business models analyse how iGFBs contribute to create value and the problem they are trying to solve, how they are integrated, their cost versus benefits and provide a brief overview of their risks. After that, the Business Model Canvas is drawn following the main trends in BRIDGE Business Models Working Group. Before that delving to these details, single-use core functionality and the main stakeholders of single-use iGFBs are analysed to obtain an overview of the capabilities of the single-use iGFBs and which entities will be integrated into the business model.

Single-use Core Functionality

Five different core functionalities for iGFBs within the scope of the WeForming project were identified:

1. **Thermal Storage Optimization**: This functionality involves optimizing thermal energy storage solutions to enhance energy efficiency in thermal management by balancing demand with renewable energy supply. Energy markets has seen increasing interest in thermal energy solutions, primary driven by the need for energy efficiency and cost reduction in buildings. Current revenue opportunities around energy efficiency projects and renewable energy integration offer a conducive environment for such implementations. However, detailed optimization and integration with an EMS for real-time management are less common and represent a novel approach. Europe wide, these methodologies are well aligned with recent legislation around self-consumption and energy communities across Europe, i.e., Decree-law 24/2021 in Spain, Decree-law 162/2019 and 15/2022 in Portugal, the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz) in Germany or the Law 2020 on Self-Consumption and Renewable Energy Communities in Luxembourg.
2. **Solar PV Self-Consumption**: Maximizing on-site generated solar energy consumption aligns production with consumption demands, reducing grid reliance and promoting sustainability. Solar PV self-consumption is actively promoted, with incentives and schemes aimed at residential, commercial, and industrial sectors in countries such as Portugal, Spain, Germany and Luxembourg. The market already sees a significant implementation of solar PV solutions, but the integration with Energy Management System (EMS) for optimization across multiple building operations (like HVAC, lighting) is an area of ongoing development. The European regulation encourage the uptake of such systems as depicted for the thermal storage optimization.
3. **Trade of Flexibility in Balancing Markets:** Monetizing the building's flexibility by offering it as load-frequency control products in balancing markets, exploring new revenue streams. Participation in balancing markets with flexibility services is an emerging opportunity across Europe. Platforms such as PICASSO, MARI, and TERRE provide new economic opportunities for Balance Service Providers to participate in pan-European markets. Besides, counties where these platforms are not yet active also enable the participation of buildings for reserves, if sufficient tests are passed. The recent Electricity Market Reform (European Council, 2024) and the liberalization of energy markets have started to open doors for such innovative participation,

though it is at a nascent stage. However, specific frameworks and mechanisms for building-level participation are evolving.

4. **Minimize Costs of Energy Bills Using Load Shifting**: load shifting strategies to reduce energy bills by leveraging flexible loads and Time-of-Use (ToU) tariffs. ToU tariffs and demand response programs are available in the most of the European energy markets, with growing adoption among commercial and industrial users as the case of Germany and Spain. The integration of these strategies with advanced EMS for automated and optimized load shifting is a frontier being explored, as initiatives such as those achieved by hotels in Hamburg and Norderstedt. Nevertheless, their final adoption depends on the level of deployment of smart metering and the availability of these tariffs in each region. In general terms, the regulation encourages these proposals.
5. **Peak Shaving to Minimize Grid Fees:** Using Distributed Energy Resources (DER) or Energy Storage Systems (ESS) for peak shaving to avoid exceeding contracted power and minimize grid fees, examples of this application were found in Cloché d'Or (EagleStone, 2024). Peak shaving applications, especially using battery storage, are becoming more common in response to the high grid fees during peak times. However, the sophisticated management of this process through an EMS integrated with predictive analytics represents a progressive step forward. The regulatory environment that penalizes peak consumption indirectly supports the adoption of peak shaving technologies. While specific incentives for peak shaving are not explicitly outlined, the overall push for energy efficiency and grid optimization aligns with this functionality.

Stakeholder mapping

During the development of the task the following stakeholders have been identified. Stakeholders related with grid have been identified following the Harmonised Role Models developed by ENTSO-E (ENTSO-E, 2023). This section provides a brief description of them and the challenges they are currently facing:

1. **Building Managers and Operators**: Responsible for overseeing the integration and operation of various energy systems, ensuring alignment with efficiency goals. Their efforts result in cost savings and improved sustainability within buildings. They are facing challenges regarding the **operational efficiency** ensuring that the systems operate a peak efficiency consistently without need to regularly update the building. This is especially relevant regarding the **maintenance** of **integrated energy systems** within the same building.
2. **Energy Service Companies (ESCOs) and Technology Providers**: Design, implement, and manage energy solutions, including innovative technologies and services. They expand their portfolios and demonstrate capabilities to deliver advanced solutions that enhance energy efficiency and grid stability. To do so, they face challenges regarding the **technology implementation of advanced energy solutions** while trying to acquire new customers demonstrating return on investment.
3. **Grid Operators (TSO/DSO):** Grid operators are responsible for managing and maintaining the electricity grid infrastructure. They ensure the reliability and stability of the grid by balancing electricity supply and demand, managing transmission and distribution networks, and addressing any issues that may arise. In a system with ever-increasing penetration of renewable, grid operators are facing challenges regarding the **grid stability** during operation and infrastructure maintenance on such variant conditions.
4. **Aggregators:** Aggregators act as intermediaries between energy producers and consumers, pooling together various DERs such as solar panels, battery storage systems, and demand response programs. They aggregate these resources to provide grid services such as frequency regulation, demand response, and capacity management. Aggregators play a crucial role in enhancing grid flexibility and stability by optimizing the use of DERs and coordinating their

participation in energy markets. But to do so, they need to overcome the challenge of **resource coordination** of the DERs while they are participating in energy markets.

5. **Tenants and Retailers**: Benefit from energy systems deployed within buildings, actively participating in demand response programs, and potentially reducing operational costs. Their engagement contributes to the overall success of energy management initiatives. To achieve that, single-use iGFBs should focus on the challenge of **reducing their operational costs** while not jeopardising the comfort and usability of the buildings.
6. **Regulatory Authorities:** Provide frameworks and guidelines that govern the implementation of energy management initiatives. They play a critical role in promoting efficiency and sustainability objectives through policy development and enforcement. Nevertheless, this is a tough hurdle since they need **to encourage sustainability** through effective policy frameworks while enforcing energy management regulations.
7. **Investors and Financial Institutions**: Provide capital for energy system installations, supporting upfront financial investment. They achieve returns on investment through reduced energy costs and potential incentives, contributing to the transition to a more sustainable energy landscape. In this sense, their main concern is the **risk of such an investment**, needing for comprehensive tools that provide them with accurate measures of the risk associated with energy projects in single-use iGFBs.
8. **Environmental Advocacy Groups**: Advocate for environmental benefits associated with energy management practices. They support sustainability goals, raise public awareness, and drive industry change towards more environmentally friendly practices, raising awareness in the public and influencing policy.

3.2.1. One Stop Shop

One Stop Shop (OSS) models have emerged as fundamental frameworks for designing the delivery of comprehensive energy renovation services, especially in residential sectors. The analysis of existing OSS initiatives and their potential adaptation to the commercial building sector, specifically for iGFBs reveals several key insights. OSS initiatives are generally categorized into four primary business models, each varying in the level of service integration and responsibility:

1. **Facilitation Model**: Focuses on raising awareness and providing initial advice on energy services, offering a low threshold for entry but limited direct assistance in implementation.
2. **Coordination Model**: Offers a more involved approach by coordinating existing market actors and services to ensure stakeholders receive support. Nevertheless, the responsibility for the project results remains with individual service providers.
3. **All-inclusive Model**: Acts as a single point of contact for stakeholders, overseeing the entire project from start to finish, including the assurance of work quality and energy savings.
4. **ESCO-type Model**: Like the all-inclusive model but with a specific emphasis on delivering energy savings. The OSS entity guarantees these savings and is compensated through them, aligning long-term energy performance with financial incentives.

Given the focus of the WeForming Project, the Business Model based on OSS for Single-use iGFBs follows the ESCO-type model, focusing on the delivery of energy savings and grid forming capabilities of the buildings.

Value Proposition Analysis

The One Stop Shop model for single-use iGFBs offers a comprehensive solution tailored to meet the complex energy needs of commercial buildings. By focusing on the ESCO-type model, the OSS ensures the delivery of substantial energy savings and enhanced grid stability. This model provides end-to-end services, from initial assessment and planning to the implementation and maintenance of advanced energy management systems, renewable energy integration, and dynamic grid interaction capabilities. Key advantages include:

- guaranteed energy savings,
- reduced operational costs, and
- improved sustainability.

The OSS approach also ensures continuous performance monitoring and quality assurance, offering peace of mind to stakeholders by validating energy efficiency measures and grid support contributions. The **primary customers** for the OSS model in the context of single-use iGFBs include:

- building managers and operators,
- ESCOs and technology providers,
- tenants and retailers,
- grid operators (TSO/DSO), and
- investors and financial institutions.

Building managers and operators benefit from streamlined integration and operation of energy systems, reducing complexity and operational costs. ESCOs and technology providers can expand their portfolios with advanced, reliable solutions, while tenants and retailers enjoy lower energy costs and improved building comfort. Grid operators benefit from enhanced grid stability through intelligent energy management and demand response capabilities. Finally, investors and financial institutions see reduced risks and assured returns on investment due to the performance guarantees provided by the OSS.

The **OSS model provides a single point of contact for all energy management needs**, coordinating and overseeing the entire project lifecycle. This includes conducting energy audits, designing tailored energy solutions, implementing advanced energy management systems, integrating renewable energy sources, and ensuring compliance with regulatory requirements. This approach addresses the challenges faced by each stakeholder, from ensuring operational efficiency and reducing costs for building managers to demonstrating ROI and acquiring new customers for ESCOs.

Customers should be willing to pay for the OSS services because it directly addresses their key challenges and pain points. The integration of OSS business model for single-use iGFBs necessitates careful consideration of the demands and complexities of iGFBs, they must address several critical challenges faced by stakeholders:

- For building managers and operators, the OSS model ensures operational efficiency and reduces the burden of maintenance and upgrades, which translates into significant cost savings and improved sustainability. OSS providers can integrate new technologies and practices while building codes and energy efficiency standards become more stringent.
- ESCOs and technology providers can offer more advanced, integrated solutions to their clients, thus enhancing their market competitiveness.
- Tenants and retailers benefit from reduced energy bills and improved comfort, making it an attractive proposition. In addition, they indirectly benefit for improved quality of service by procuring feedback to OSS providers, which will help to implement new and refined advanced EMSs.
- Grid operators gain from improved grid stability, reducing the risks associated with fluctuating energy supply and demand. In addition, they can also benefit for long-term contracts typical for OSS concepts, achieving economies of scale when deploying this type of business models for single-use iGFBs in their respective networks.

- Investors and financial institutions see a lower risk profile and assured returns on their investments due to the performance guarantees and continuous monitoring provided by the OSS. The incorporation of OSS concept is especially interesting as they can be seen as “sustainable bundles” for investors aiming to incorporate eco-friendly business model into their portfolio.

SWOT Analysis

The SWOT matrix highlights the OSS model's strengths in offering comprehensive energy solutions and guaranteed savings, while also recognizing weaknesses like high initial costs and regulatory dependencies. Opportunities arise from the increasing demand for energy efficiency and supportive regulations, whereas threats include competition and technological changes. Nevertheless, the OSS model for single-use iGFBs must navigate several risks to ensure successful integration.

- Market competition from specialized service providers could pose a challenge, requiring OSS providers to continually innovate and demonstrate their comprehensive value proposition.
- Technological obsolescence is another risk, necessitating constant updates to service offerings to keep pace with advancements.
- Dependency on regulatory changes could require unforeseen adjustments in service offerings, highlighting the importance of maintaining flexibility.
- Additionally, client acquisition and retention are critical, as building owners may be cautious about committing to bundled services.

This is summarized in Figure 7.

	Helpful	Harmful
Internal Origin	**Strengths**	**Weaknesses**
	Clients' processes streamlining	High initial setup costs
	Adaptation to market & regulation changes	Dependency on regulatory frameworks
	Economies of scale	Technological obsolescence risk
	End-to-end service integration	Client acquisition and retention challenges
External Origin	**Opportunities**	**Threats**
	Increasing demand for energy efficiency	Market competition from specialized providers
	Growth in renewable energy adoption	Rapid technological changes
	Supportive European regulations	Regulatory uncertainties
	Emerging flexibility markets	Dependency on smart metering and ToU tariffs availability

FIGURE 7. SWOT MATRIX FOR THE ONE STOP SHOP BUSINESS MODELS FOR SINGLE-USE IGFBS.

While the deployment of the OSS business model involves initial setup costs and ongoing operational expenses, **the benefits significantly outweigh these costs**. The integration of advanced energy management systems and renewable energy technologies in single-use iGFBs leads to substantial energy savings and operational cost reductions. Enhanced building value and compliance with sustainability standards further contribute to the overall benefits.

Lean Model Canvas

The Lean Model Canvas for Single-Use iGFBs using OSS concept is outlined in FIGURE 8. The Lean Model Canvas outlines the main problems such as high energy costs and grid instability and provides solutions through advanced energy management and renewable integration. Key metrics focus on energy savings and cost reductions, while the value proposition emphasizes comprehensive, guaranteed energy savings. The model's advantage lies in its performance guarantees and monitoring. Channels for reaching customers include direct sales and strategic partnerships, targeting segments like building managers and

ESCOs. The cost structure includes setup and operational costs, with revenue streams from service fees and long-term contracts.

Problems	Solutions	Value Proposition	Advantage	Customer Segments
High energy costs Grid instability Regulatory compliance	Advanced energy management systems Renewable energy integration Dynamic grid interaction capabilities	Comprehensive energy savings Grid stability services Performance guarantees	Guaranteed performance Continuous monitoring Simplicity Cost effective	Building managers and operators ESCOs and technology providers Tenants and retailers Grid Operators Investors and financial institutions
Existing Alternatives	**Key metrics**	**High-Level Concept**	**Channels**	**Early Adopters**
Energy-efficient retrofits Traditional grid management	Energy savings achieved Operational cost reductions Grid stability enhancements	Single provider of bundled solutions End-to-end project management	Direct sales Strategic partnerships Online platforms	Commercial building operators

Cost structure	Revenue Streams
Initial set-up and technology investment Operational and maintenance expenses Marketing and customer acquisition costs Services updated: training and equipment	Service fees: Different subscription plans Long-term contracts: End to end life cycle of the product Performance-based incentives Upselling: selling additional products

FIGURE 8: LEAN MODEL CANVAS FOR SINGLE-USE IGFBS – ONE STOP SHOP

3.2.2. Product as a Service Systems (PaaS)

PaaS in the energy sector is also known as the Energy-as-a-Service (EaaS) model which fundamentally shifts the traditional ownership and operational responsibilities for energy infrastructure to a service-based model. In this model, customers pay for energy **services without needing to make any upfront capital investment**, which can dramatically alter how energy efficiency and renewable energy projects are deployed, especially in the context of iGFBs.

EaaS typically involves a subscription-based service where the customer enjoys the benefits of energy-efficient technology or renewable energy sources without having to purchase or manage these systems directly. This model not only provides customers with immediate access to advanced technologies and energy savings but also shifts the responsibility for the maintenance and operation of these systems to the service provider. Such arrangements can include everything from energy-efficient lighting and HVAC systems to on-site renewable energy production like solar panels. There are several variations of the EaaS model, covering different aspects of energy management and efficiency improvements:

1. **ESCO Model:** Early Energy Service Companies focused on providing energy efficiency upgrades under performance-based contracts, where repayment was tied to the energy savings achieved.
2. **Energy Service Agreement** (ESA): In this model, service companies finance energy efficiency upgrades, and customers repay the investment through the savings realized on their energy bills over time.
3. **Managed Energy Services Agreement** (MESA): Similar to ESAs but often includes broader management of a facility’s energy usage in exchange for payments based on previous bills. This model suits customers lacking in-house energy management expertise.

4. **Solar-as-a-Service**: A specific application of EaaS for deploying solar energy systems at no upfront cost to the customer, who then pays for the solar energy produced at a rate typically lower than the utility's retail price.

Value Proposition Analysis

The "Product as a Service" (PaaS) model for single-iGFBs presents a transformative approach to energy management. This model aligns well with the needs of diverse stakeholders by offering advanced energy solutions without the need for significant upfront capital investments. The value proposition is centred around several key advantages:

Cost Efficiency: One of the primary advantages for customers is the elimination of substantial initial costs associated with purchasing and maintaining advanced energy systems. Instead, customers pay a subscription fee that includes access to the latest energy-efficient technologies, maintenance, and operational services. For example, building managers can benefit from state-of-the-art energy management systems without having to invest heavily upfront.

Flexibility and Scalability: The PaaS model offers flexibility, allowing services to be tailored and scaled according to the specific needs of the building. This is particularly beneficial for iGFBs, which can adjust their energy services based on real-time occupancy and usage patterns, optimizing energy consumption and costs.

Continuous Improvement: Customers benefit from continuous upgrades and updates to their energy systems. The service provider ensures that the latest technologies and best practices are implemented, keeping the building's energy systems at peak efficiency without additional costs for the customer.

Expert Support and Maintenance: The PaaS model includes comprehensive support and maintenance services managed by the provider. This reduces the operational burden on building staff and ensures that energy systems function smoothly and efficiently.

The PaaS model integrates seamlessly with the operational and financial frameworks of iGFBs, addressing several critical challenges faced by stakeholders:

- The primary customers for this model are the management teams of iGFBs, including operations, sustainability, and financial planning departments. These stakeholders seek to enhance energy efficiency and reduce operational costs while maintaining quality of service. PaaS schemes through service agreements allows providers to monitor and improve service quality through client feedback and operational data.
- Additionally, tenants and retailers within iGFBs indirectly benefit from lower utility costs and improved environmental conditions, making the overall environment more appealing to visitors and patrons. PaaS models are highly adaptable, allowing for quick integration of new technologies and methodologies to meet evolving energy efficiency standards. This ensures that buildings always have access to the most effective solutions

Services are offered through an initial consultation to assess the building's energy systems, followed by the deployment of tailored technologies and ongoing support. Customers should pay for these services because the PaaS model provides significant operational savings with flexible pricing models, such as performance-based contracts. PaaS business models also help to achieve sustainability goals, transfers technological and operational risks to the service provider, and enhances the building's reputation as a leader in sustainability.

SWOT Analysis

Implementing a PaaS model involves ongoing investments in technology and expertise to maintain competitive service delivery. However, the benefits include a steady revenue stream for providers, access to the latest technologies for clients without upfront costs, and improved energy efficiency.

The main risks include technological complexity, dependence on customer subscriptions, market competition, and regulatory changes. These risks necessitate a robust strategy for technology management, customer relationship maintenance, competitive differentiation, and regulatory compliance.

The SWOT matrix depicted in FIGURE 9 underscores the PaaS model's ability to provide significant advantages while highlighting areas that require strategic focus to mitigate risks regarding rapid technological advancements and customers subscriptions dependences.

	Helpful	Harmful
Internal Origin	**Strengths**	**Weaknesses**
	Access to new technology without significant expenditure Deep customers relationships through data insights Predictable budgeting for energy management services	Continuous investment in technology and expertise Dependence on sustained customers subscriptions Technological risks transferred to investors
External Origin	**Opportunities**	**Threats**
	Expanding energy-as-a-service market driven options Cross-selling additional services and upgrades Leveraging data insights for continuous improvement	Increased competition from other companies adopting service-based models Rapid technological advancements Regulatory changes affecting energy markets

FIGURE 9. SWOT MATRIX FOR THE PRODUCT AS A SERVICE BUSINESS MODEL - SINGLE USE IGFBS

Lean Model Canvas

The Lean Model Canvas illustrated in FIGURE 10 shows the PaaS model's approach to addressing the energy management needs of iGFBs. It highlights the significant value offered through flexible, cost-efficient, and scalable energy solutions, while also outlining the key metrics, customer segments, and revenue streams that drive the business model. This canvas provides a clear and concise framework for understanding the strategic components and operational dynamics of the PaaS model for single-use iGFBs.

Problems	Solutions	Value Proposition	Advantage	Customer Segments
High upfront costs of energy systems Maintenance and operation Ensuring continuous technology upgrades	Subscriptions-based access to energy efficient technologies Comprehensive maintenance Support services Continuous system upgrades	Cost savings from reduced energy consumption Optimisation Cost-efficient, flexible and scalable solutions No upfront required	Provision of cutting-edge solutions without capital Strong customer relationships Data-driven insights provision	Building managers and operators Energy service companies Technology providers Tenants and retailers
Existing Alternatives	**Key metrics**	**High-Level Concept**	**Channels**	**Early Adopters**
Traditional Purchase models In-house management Periodic capital investments	Cost savings Subscription renewal rates Customer satisfaction	Continuous access to latest technologies and expert support	Direct sales to building management Partnerships with ESCOs Marketing in forums	Tenants
Cost structure			**Revenue Streams**	
Ongoing investments in technology, staff training Maintenance and operational costs for service delivery			Subscription fees for energy services Performance-based contracts tied to energy systems	

Marketing and customer acquisition expenses Data analytics OPEX expenses	Additional services Upgrades offered to existing customers

FIGURE 10. LEAN MODEL CANVAS FOR SINGLE-USE IGFBS – PRODUCT AS A SERVICE

3.2.3. Innovative Financial Schemes

Creative financing models like on-bill financing, energy savings obligations, and crowdfunding can make energy-efficient renovations and the adoption of smart technologies more accessible.

Value Proposition Analysis

Innovative Financial Schemes (IFS) for single-use iGFBs offer multiple advantages to a range of stakeholders, addressing key challenges and delivering significant benefits. These schemes minimize or eliminate upfront costs for adopting energy-efficient technologies and services, reducing financial barriers and facilitating access to advanced energy systems. The following stakeholders could benefit from this model:

- Building managers and operators, who face challenges in maintaining operational efficiency and ensuring systems operate at peak efficiency, can leverage IFS to implement necessary upgrades without immediate financial strain.
- For ESCOs and technology providers, IFS offers a platform to showcase their advanced energy solutions, attracting new customers by demonstrating tangible returns on investment.
- Tenants and retailers, who benefit from reduced operational costs and improved environmental conditions, are indirect beneficiaries of these schemes.
- Grid operators can rely on the enhanced grid stability provided by the iGFBs' advanced energy systems, while investors and financial institutions gain from the secured and predictable returns through performance-based contracts and energy savings agreements.

To offer these services, stakeholders plan to establish partnerships with financial institutions, ESCOs, and utility providers. By leveraging government incentives, grants, and community financing options like crowdfunding, they create a diversified financial ecosystem supporting energy efficiency projects. Energy performance contracting, where an ESCO manages installation and maintenance costs through energy savings, ensures that buildings pay for actual savings achieved, aligning financial incentives with performance outcomes.

Customers should pay for these services because of the long-term savings achieved through energy efficiency measures. These savings significantly outweigh the initial costs over time, providing a compelling return on investment. Additionally, achieving sustainability goals enhances tenant attraction, building valuation, and compliance with regulatory frameworks, contributing to improved building performance and market differentiation. By adopting these financial schemes, iGFBs position themselves as leaders in sustainability and innovation within the competitive commercial real estate market.

SWOT Analysis

The cost-benefit balance of deploying IFS is crucial. The costs involve interest payments, service fees, and a share of energy savings paid to finance providers. Additionally, meeting criteria for specific financing schemes might incur costs for third-party certifications or audits. However, the benefits for building owners are significant, allowing substantial energy improvements without large upfront investments. This leads to long-term operational savings, enhanced property value, and improved sustainability credentials.

Despite these benefits, risks exist. The complexity of financial agreements can lead to transparency issues and mismatched expectations. Performance-based models carry the risk of underperformance, affecting financial returns. Market and regulatory changes can impact the viability of projects financed under these schemes. Nonetheless, the inherent adaptability and alignment with energy savings mitigate many of these risks, making IFS a viable and attractive option for advancing energy efficiency in iGFBs.

This is summarised by the FIGURE 11. The SWOT analysis underscores the balanced outlook for IFS, highlighting significant strengths and opportunities while acknowledging potential weaknesses and threats that require strategic management.

	Helpful	Harmful
	Strengths	**Weaknesses**
Internal Origin	Access to projects with reduced upfront payments Can be tailored to fit specific project needs and risk profiles Project flexibility for both financers and building owners Directly aligns financial incentives with energy savings	Potential complexity and lack of understanding leading to hesitancy among building owners Reliance on accurate energy savings projections and performance of installed systems Depends on buildings' ability to adjust energy use with impacting core operations It might affect to occupant comfort
	Opportunities	**Threats**
External Origin	Growing interest in sustainability and energy efficiency Technological advancements increase attractiveness and ROI of projects Increasing regulatory pressure on building energy performance Potential for strategic partnerships with utilities and grid operators	Economic downturns or shifts in policy can affect the availability of the funding Emergence of new, more competitive financing models Potential misalignment between projected and actual energy savings Technological obsolesces and market competition

FIGURE 11. SWOT MATRIX FOR THE PRODUCT AS A SERVICE BUSINESS MODEL - SINGLE USE IGFBS.

Lean Model Canvas

The Lean Model Canvas for Single use iGFBs using IFS concept is shown in FIGURE 12. In this Business model, the Single use iGFB make use of financing schemes for innovative actions through crowdfunding, European Grants or any other competitive scheme. Key partners are building managers, technology providers, investors, aggregators, regulatory authorities and environmental advocacy groups. The value proposition greatly differs compared to the OSS and PaaS schemes since the financial barriers are reduced, and energy efficiency are greatly increased through novel solutions. In the long term, the revenues streams are maintained to operational savings and access to new and disruptive technologies at lower prices that the market. Nevertheless, this might require thoughtful audits, certifications and increased operational expenses in licenses, data analytics and work force.

Problems	Solutions	Value Proposition	Advantage	Customer Segments
Efficiency challenges ESCO acquiring new customers Grid stability Tenants seeking reduced operational costs	On-bill financing Energy performance contracting Crowdfunding	Reduced financial barriers Risk mitigation Cash flow management New capital sources for energy-efficient projects.	Alignment of financial incentives with performance outcomes Stakeholders pay only for the actual savings Reduce of financial risks Trust enhancement	Building managers and owners Tenants and retailers
Existing Alternatives	**Key metrics**	**High-Level Concept**	**Channels**	**Early Adopters**
Traditional loans Internal funding	Energy savings ROI Satisfaction among stakeholders	Making energy solutions accessible	Financial institutions and Government ESCOs, Utility providers Community financing platforms	Building managers

Cost structure	Revenue Streams
Interest payments to financing institutions Service fees Costs, audits, certifications to meet the criteria of the financing Workforce management	Performance-based contracts: different subscription plans Enhanced property value Long-term savings and sustainability credentials Interest payments

FIGURE 12. LEAN MODEL CANVAS FOR SINGLE-USE IGFBS - INNOVATIVE FINANCIAL SCHEMES

3.2.4. New revenue models

In the WeForming project, new revenue models can be developed based on the project's capabilities to optimize energy use and interact with the energy market. Here are some potential new revenue models that could be considered for the single-use iGFBs depending on its main activity.

Demand Response (DR) Participation
Buildings can earn revenue by participating in DR programs, where they reduce or shift their energy usage during peak times based on grid signals. By adjusting energy consumption in real-time, buildings help balance supply and demand on the grid, for which they receive financial incentives.

Grid flexibility market Services
Buildings with energy generation (like solar PV) or storage capabilities (like battery systems) can provide ancillary services to the grid, such as frequency regulation or voltage support. This can open up new revenue streams as buildings help maintain grid stability and resilience[79].

P2P Energy Trading
Utilizing blockchain technology, iGFBs could sell excess solar energy directly to nearby consumers or businesses. For example, on sunny days when the solar panels produce more electricity than the building can use, the surplus could be sold to a nearby office building or retail outlet, providing an additional income stream while supporting local renewable energy use[80].

Carbon Credit Trading
By significantly reducing its energy consumption and increasing its use of renewable energy, iGFBs could generate carbon credits under a cap-and-trade system. These credits could then be sold to other companies struggling to meet their carbon reduction targets, creating a new revenue stream for the building while promoting environmental sustainability[81].

On-Bill Financing
Utilities or service providers front the cost of energy improvements, and the building owner repays the investment over time through their utility bill. The WeForming project could partner with utilities to offer on-bill financing, providing a convenient way for building owners to finance energy upgrade

[79] https://www.e-redes.pt/en/news/2022/12/12/first-steps-flexibility-market-Portugal
[80] https://www2.deloitte.com/nl/nl/pages/energy-resources-industrials/articles/peer-to-peer-energy-trading.html
[81] https://carboncredits.com/the-ultimate-guide-to-understanding-carbon-credits/

Data Monetization

The analytics capabilities of the WeForming project could be leveraged to gather valuable data on energy usage patterns, which can be anonymized and sold to interested parties, such as energy market analysts, urban planners, or technology developers[82].

Value Proposition Analysis

Single-use iGFBs offer a suite of innovative revenue models that capitalize on their advanced capabilities in energy management and market interaction. These models present several compelling advantages to a diverse array of stakeholders:

Financial Benefits: Single-use iGFBs enable significant energy cost savings and new revenue streams. By participating in DR programs, buildings can reduce their energy usage during peak times, earning financial incentives from grid operators or utility providers. This translates to direct cost savings and potential revenue generation from reduced utility rates. Additionally, engaging in grid flexibility services, such as frequency regulation or voltage support, allows buildings to earn revenue by providing ancillary services that support grid stability.

Sustainability and Grid Stability: iGFBs play a crucial role in enhancing grid stability and advancing sustainability goals. By dynamically adjusting energy consumption in response to grid signals, iGFBs help balance supply and demand, contributing to a more stable and resilient grid. This is particularly important given the increasing variability of renewable energy sources. Moreover, by generating and trading carbon credits, iGFBs promote environmental sustainability, supporting broader climate goals while generating additional income.

Operational Efficiency and Financial Management: The adoption of advanced EMS facilitates improved operational efficiency within iGFBs. These systems enable real-time monitoring and optimization of energy usage, leading to reduced operational costs. Financial management is further streamlined through mechanisms like On-Bill Financing (OBF), which eliminates the need for significant upfront investments. Instead, the costs are repaid through utility bills, making energy efficiency projects more accessible and financially manageable.

Enhanced Property Value and Stakeholder Engagement: Investments in energy efficiency and renewable energy initiatives increase the property value of iGFBs, attracting sustainability-conscious tenants. Furthermore, data monetization strategies offer unique insights into energy usage patterns, which can be valuable to energy market analysts, urban planners, and technology developers. This not only provides a new revenue stream but also enhances stakeholder engagement and supports informed decision-making in energy management.

Target Customers: The primary customers for these value propositions include building owners and managers, tenants, local businesses, and residents who benefit from lower energy costs and sustainable practices. ESCOs, aggregators, utility companies, and grid operators also gain from improved grid stability and enhanced energy management capabilities. Additionally, businesses seeking carbon offsets, research institutions, government bodies, and real estate consultants are key customers for data-driven insights and sustainability initiatives.

SWOT Analysis

The SWOT analysis highlights the strategic position of single-use iGFBs in leveraging new revenue models. Strengths such as financial incentives and sustainability enhancements position them favourably, while

[82] https://medium.com/@indigoadvisory/strategies-to-monetize-energy-data-how-utilities-can-increase-their-earnings-per-byte-68b066f97715

weaknesses and threats emphasize the need for careful risk management and regulatory adaptation. The main deployment risks are summarised below:

Adaptability and Efficiency Requirements: DR programs are designed to be highly adaptable, meeting the evolving needs of both the grid and participating buildings. They align with changing energy efficiency standards and grid requirements, allowing continuous adaptation to new technologies and practices. Quality of service is maintained through constant communication and feedback loops between grid operators and participants, ensuring energy reduction efforts do not adversely affect building operations or occupant comfort.

Environmental Impact: DR programs significantly contribute to environmental sustainability by optimizing grid operations and reducing reliance on peak power plants, which are often the most polluting. Additionally, carbon trading directly incentivizes the reduction of greenhouse gas emissions, supporting global climate goals and leading to significant environmental benefits.

Cost Adaptation: The financial structures of DR programs offer various incentives that can adjust to market conditions, ensuring that participation remains economically viable. On-Bill Financing structures allow costs to be spread over time, aligning with the energy savings generated from projects. This approach ensures that financial obligations are manageable and potentially lead to neutral or positive cash flow scenarios for buildings.

Operational and Technological Risks: Deploying these business models involves operational and technological risks, such as potential disruptions from energy adjustments and the need for compatible systems. Overcoming these challenges requires investment in robust technological infrastructure and meticulous planning to ensure seamless integration with grid signals and effective management of energy adjustments.

Market and Regulatory Risks: Changes in market rules or regulatory frameworks can impact the feasibility and profitability of DR and P2P trading platforms. Navigating these risks necessitates staying abreast of regulatory developments and maintaining flexibility to adapt to changing conditions

The Strengths, Weaknesses, Opportunities and Threats for New Revenue Models for single-use iGFBs are summarised in the SWOT chart depicted in FIGURE 13:

	Helpful	**Harmful**
	Strengths	**Weaknesses**
Internal Origin	Provides direct financial incentives and new revenue streams. Enhances sustainability profiles and contributes to grid stability. Utilizes existing building management systems for operational benefits. Offers pricing flexibility and potential cost savings.	Potential operational disruptions due to new technology. Dependence on regulatory frameworks and ability to adjust energy use. Requires investment in technology and training. Complexity in data management and potential privacy concerns.
	Opportunities	**Threats**
External Origin	Growing demand for grid flexibility due to renewable energy penetration. Advances in energy management and blockchain technologies. Expanded programs and incentives from utilities and grid operators. Potential new markets for carbon credits and valuable data insights.	Regulatory and market changes affecting profitability. Increased competition for DR incentives. Risk of non-compliance with DR event requirements. Cybersecurity risks associated with digital transactions and data handling.

FIGURE 13. SWOT MATRIX FOR NEW REVENUE MODELS – SINGLE USE IGFBS

Lean Model Canvas

The Lean Model Canvas succinctly outlines the core aspects of the new revenue models for single-use iGFBs, focusing on solving key problems through innovative solutions that generate value for diverse customer segments. By leveraging advanced technologies and flexible financial structures, these models offer significant cost savings, revenue opportunities, and sustainability benefits, aligning well with market demands and regulatory requirements. The canvas emphasizes the importance of robust financial planning, continuous adaptation to market and regulatory changes, and effective stakeholder engagement to ensure the successful implementation and long-term viability of these revenue models.

Problems	Solutions	Value Proposition	Advantage	Customer Segments
Grid instability during peak demand	Demand Response Programs	Financial savings	Direct integration with existing EMS	Building owners and managers
High operational costs	Grid flexibility services	New revenue streams using new solutions	Flexibility in pricing and participation models	Tenants and local businesses
Lack of participation in energy markets	Peer-to-peer energy trading	Operational efficiency increase	Strong alignment with sustainability and regulation	ESCOs and aggregators
Regulatory compliance	Carbon credit and on-bill financing	Increase property value		Utility companies and grid operators
Sustainability goals	Data monetization and advanced EMS integration			Sustainability-conscious entities
Existing Alternatives	**Key metrics**	**High-Level Concept**	**Channels**	**Early Adopters**
Traditional power plants and tariffs	Energy costs savings	Leveraging new revenue models to increase benefits	Partnerships with utility providers and technology platforms	Building owners and managers
Non-interactive energy systems	Carbon credits generated	Increase property value	Direct engagement with building managers	ESCOs and aggregators
Limited carbon trading	Customer participation and engagement		Educational programs	
	Data sales			

Cost structure	Revenue Streams
Initial investments in technology and EMS: Software, Metering, Data infrastructure	Incentives from DR programs and Payments for grid flexibility services
Ongoing maintenance and operational costs: licenses, specialized workforce, data analytics	Long term operational savings and sustainability credentials
Costs associated with data privacy and security	Revenue streams from P2P energy trading and carbon credits
New financing: audits, certifications, continuous investments	Subscription fees for data access and analytics services

FIGURE 14. LEAN MODEL CANVAS FOR SINGLE-USE IGFBS - NEW REVENUE MODELS

3.3. Potential future business models for multi-use iGFBs

Multi-use iGFBs are more complex and interactive than single-use iGFBs. They are designed to perform **multiple energy-related functions** that benefit both the building and the grid. For instance, a multi-use iGFB may have solar panels, energy storage systems, and smart HVAC systems that work together to optimize energy efficiency, provide grid services, and enhance the occupants' comfort.

The term "*multi-functional integration*" refers to the building's ability to combine these different energy functions into a cohesive, smart system that can adapt to changing energy needs and market conditions. The integration allows the building to participate in a variety of grid services, such as demand response, frequency regulation, and energy trading.

"*Wider stakeholder interaction*" encompasses a broader range of engagements that reflect the diverse functionality of the building. It involves collaboration with a larger group of stakeholders, including energy market operators, regulators, local community groups, and potentially other buildings and infrastructure.

This interaction aims to maximize the economic, environmental, and social benefits of the iGFB's multi-functional capabilities.

This section will analyse the potential future business model for multi-use iGFBs. First analysing the multi-use core functionality of iGFBs, then identifying potential stakeholders per functionality and providing different business models for OSS, PaaS, IFS and NRM.

These business models analyse how iGFBs contribute to create value, how they are integrated, their cost versus benefits and provide a brief overview of their risks. After that, two management tools are used to provide an overview of them: SWOT and the Lean Model Canvas.

Multi-use Core Functionality

Five different core functionalities for multi-use iGFBs within the scope of the WeForming project were identifies. It worth noticing that the links within the different technologies involved in each core functionality is intrinsic to the building, meaning that, there are couplings at system level of the iGFB.

- **Multi-Port Power Processing Hub**: This involves the integration of various energy sources (PV, BESS, EV, and Fuel Cells) into a centralised hub, while efficiently manage and regulate internal power flows. Grid forming capabilities will be necessary here to improve stability and resilience and being able to create a grid from scratch if needed. In some cases, this also involves the deployment of local distributed generation or even to integrate public infrastructure to optimise energy systems.
- **Intelligent mobility and EV Charging Management**: Some multi-use iGFBs manage a large fleet of EVs, being crucial to optimize the charging infrastructure, including Vehicle-to-Grid (V2G) technology if possible. Others might opt to establish a network of e-mobility charges both for cars and bicycles. There is also room to include car-sharing initiatives within the scope of the business model of the multi-use iGFBs, as this has the potential of optimise the energy use and maximise the usage of the vehicles.
- **Local Thermal Distribution Network**: Integration of heat pumps, storage systems, geothermal systems, and greywater heat recovery, this also involves the optimal control for efficient thermal energy distribution.
- **Data monetization through services**: This means that the multi-use iGFBs does not only focus on traditional energy intensive business models, but also in emerging new ones such as data-related business models. This could bring potential for AI/ML-based forecasting and optimization tools or real-time monitoring and control of energy assets services.
- **Interoperability and Market Integration**: Interaction with DSOs and participation in energy and service markets. For some multi-use iGFBs in the context of WeForming there is a strong interest in being able of deploy energy efficient and cost-effective solutions to deal with seasonality in the power demand.

Multi-use Stakeholder mapping

- **Direct Customers**: Customers are the end-users or beneficiaries of the multi-use iGFB services and functionalities. They encompass various groups with distinct needs and preferences, ranging from residential consumers and commercial entities to public sector stakeholders. Some examples are: Residential consumers seeking energy efficiency upgrades, commercial entities looking for sustainable energy management solutions, and public sector stakeholders aiming to implement energy-efficient infrastructure.
    - Residential customers face challenges regarding energy efficiency updates due to their high costs, and hurdles in integrating and maintaining integrated energy systems, which lead them to reliability concerns of multi-functional systems.

- Commercial entities might face operational disruptions with the potential downtime during system upgrades or maintenance. They need to justify the investment with respect to long-term savings while being compliant with the regulation.
  - Public sector stakeholders might face challenges due to limited funding for large-scale energy efficiency projects, this might affect to the public perception and the regulatory compliance of the energy policies.
- **Regulators and Policy Makers**: Regulators and policy makers shape the regulatory environment and set guidelines that influence the deployment and operation of multi-use iGFBs. They play a pivotal role in fostering an enabling regulatory framework that supports innovation and sustainability. Some examples are government agencies responsible for energy regulations, local authorities overseeing building codes and permits, and regulatory bodies managing energy markets. These regulatory bodies might face challenges regarding the:
  - Adaptation to deploying new regulation to maintain the pace with rapid technological advancements and ensuring that regulations are supportive.
  - Create regulations and maintain market stability and incentive structuring all socioeconomic groups, ensuring that all the interested parties have access to the benefits of using multi-use iGFBs.
- **Energy Market Operators**: Energy market operators facilitate the integration of multi-use iGFBs into the broader energy market landscape. They manage the trading platforms, grid operations, and market mechanisms that enable participation in grid services and energy trading. Some examples are: Independent system operators (ISOs), energy exchanges, and market operators responsible for demand response programs and ancillary services.
  - Deploying market mechanism that enable to maintain grid stability while integrating new technologies and renewable energy is key for energy market operators. This might have multiple challenges such as the coordination and communication between different participants or even cybersecurity vulnerabilities introduced by interconnected systems.
- **Technology Providers and Integrators**: Technology providers and integrators supply the hardware, software, and expertise necessary to implement and optimize the various energy-related functions within multi-use iGFBs. They enable the seamless integration of renewable energy sources, energy storage systems, and smart building technologies. Some examples are: Solar panel manufacturers, energy storage system providers, HVAC system integrators, and smart building automation companies.
  - Technology providers might face challenges regarding the interoperability of the generated solutions among different technologies in a multi-use setting.
  - They also should carefully consider the technological maturity, given the market needs for integrated energy systems.
  - Handling these new technologies might face challenges regarding maintaining the cost structure while escalating.
- **Community Groups and Advocacy Organizations**: Community groups and advocacy organizations represent the interests of local communities and stakeholders, advocating for sustainable energy practices, equitable access to energy resources, and community engagement initiatives related to multi-use iGFBs. Some examples are: Environmental Non-Governmental Organisations (NGOs), community energy cooperatives, and advocacy groups focused on energy justice and equitable development.

3.3.1. One Stop Shop concept.

The One Stop Shop business model for multi-use iGFBs provides a centralized hub for consumers or businesses seeking energy-efficient renovation solutions. It simplifies the energy transition process by offering a comprehensive range of services and products tailored to individual needs. Through integration with a digital platform, customers benefit from real-time energy management and cost-effective solutions. This model aims to enhance customer satisfaction, reduce environmental impact, and strengthen community engagement by offering customized, efficient, and sustainable energy solutions.

Value proposition

The OSS concept for multi-use iGFBs presents a solution to the challenges faced by various stakeholders being possible to further congregate a wide range of energy-efficient solutions into a centralised hub. The OSS offers several advantages to customers of multi-use iGFBs, including:

Simplification of Energy Transition: By providing a consolidated suite of services, the OSS simplifies the transition to renewable energy, reducing the need for customers to navigate complex market options.

Customized Solutions: Tailored services match specific climatic, energy, and infrastructural needs, ensuring that solutions meet individual requirements effectively.

Real-time Energy Management: Integration with a digital platform enables real-time monitoring and management of energy consumption, empowering customers to make proactive adjustments and optimizations.

Cost and Energy Efficiency: Through aggregated procurement and streamlined processes, customers benefit from reduced costs in installation and operation, along with increased energy savings.

Community Engagement and Support: Strengthening community bonds by providing energy solutions that contribute to collective benefits, such as reducing environmental impact and enhancing local sustainability.

The OSS plans to offer services to several customer segments, among which residential and commercial entities are highlighted. Besides, the OSS BM also plan to provide different services to Public Sector stakeholders, agricultural enterprises and tourism businesses through:

Digital Integration: Utilizing advanced digital platforms for seamless integration of energy solutions and providing customers with a user-friendly interface for energy management.

Flexible and Intelligent Tools: Leveraging AI and machine learning for predictive analytics and optimization to support informed decision-making.

Renewable Energy Asset Management: Offering installation, maintenance, and optimization services for solar PV, batteries, and other renewable assets.

Educational and Support Services: Providing customers with knowledge and support to maximize the benefits of energy-efficient solutions.

Customers are incentivized to pay for OSS services as they provide tangible savings on energy bills, and they have the potential to increase the property value. Besides, they provide improved living standards as convenience of having a single service provided for energy related needs which further enhance customer comfort. The community also recognises the value in contributing to sustainability and reducing environmental impact through collective action. On top of that, these services enable staying ahead of regulatory changes and preparing for future energy market shifts by investing in adaptable energy systems ensures long-term benefits for customers.

SWOT Analysis

Initial deployment costs cover integrated renewable energy systems, digital platforms, and centralized services. Benefits include energy cost savings, enhanced grid stability, and potential revenue from tourism, outweighing initial investment costs.

Challenges include market acceptance, operational complexity, financial risks, regulatory compliance, and reputation management. Mitigation strategies include market studies, robust IT infrastructure, diverse financial models, continuous regulatory monitoring, and strong customer service protocols.

The SWOT analysis demonstrates that the OSS model offers comprehensive solutions and tailored services, leveraging digital integration to enhance customer experience. However, it faces challenges such as high initial deployment costs, operational complexity, and regulatory compliance requirements. Opportunities for market expansion, technological advancements, and policy support exist, but the model is threatened by competition, regulatory uncertainty, and technological risks. Overall, the OSS is well-positioned to capitalize on opportunities and mitigate threats, leveraging its strengths to overcome weaknesses and achieve sustainable growth. This SWOT analysis is summarised in FIGURE 15:

	Helpful	Harmful
	Strengths	**Weaknesses**
Internal Origin	Diverse solutions simplify energy transition Tailored Services enhance customer satisfaction Digital integration enhances customer experience	High initial deployment costs Operational complexity Regulatory compliance of the proposed solutions
	Opportunities	**Threats**
External Origin	Is a growing market Potential for innovation with advancing technology Policy support	Competitive landscape Obsolesces without continuous improvement Rapid adaptation to regulatory changes Technological risks

FIGURE 15. SWOT MATRIX FOR THE ONE STOP SHOP BUSINESS MODELS FOR MULTI-USE IGFBS.

Lean Model Canvas

By offering tailored services through a centralized hub, the OSS simplifies the energy transition process for residential consumers, agricultural enterprises, tourism businesses, and local government facilities. Leveraging digital platforms and partnerships with renewable energy providers, the model ensures real-time energy management, cost efficiency, and community engagement. Revenue streams include sales of products and services, subscription-based platforms, and commissions from energy trading activities. Key resources encompass digital energy management platforms, renewable energy assets, and skilled personnel. Key activities involve installation, consultations, platform development, and community outreach. Partnerships with suppliers, financial institutions, and government agencies optimize the business model, while cost structures encompass deployment, operational, marketing, and compliance expenses. This is summarised by FIGURE 16.

Problems	Solutions	Value Proposition	Advantage	Customer Segments
High initial deployment costs Operational Complexity Regulatory compliance Competition from traditional energy sources	Integrated renewable energy systems installation Digital platforms for RT energy management Flexible financing schemes Continuous regulatory monitoring Efficiency consultancy	Simplification of the energy transition Cost and energy efficiency Community engagement RT energy management	Comprehensive solutions Tailored to the customer End-to-end approach Digital integration	Residential customers Commercial entities Public sector stakeholders DSOs/TSOs Tourism

<table>
<tr><th>Existing Alternatives</th><th>Key metrics</th><th>High-Level Concept</th><th>Channels</th><th>Early Adopters</th></tr>
<tr><td>Traditional energy sources</td><td>Customer acquisition cost
Customer retention rate
Energy cost savings</td><td>Provide a holistic approach for handing multi-use iGFBs</td><td>Digital marketing
Straitening partnerships
Workshops</td><td>Environmentally conscious consumers
Forward-thinking businesses
Tourism</td></tr>
<tr><th colspan="2">Cost structure</th><th colspan="3">Revenue Streams</th></tr>
<tr><td colspan="2">Set up costs: Hardware, software and regulatory compliance
OPEX expenses: Marketing and staff
Research and development investments</td><td colspan="3">Service fees: energy management platform, consulting services
Long term contracts: Maintenance and Installation
Commissions from energy trading activities
Sales of products</td></tr>
</table>

FIGURE 16. LEAN MODEL CANVAS FOR MULTI-USE IGFBS – ONE STOP SHOP

3.3.2. Product as a Service Systems (PaaS)

The PaaS business model for multi-use iGFBs revolutionizes energy consumption by offering access to advanced energy systems and services without the burden of ownership. Customers benefit from optimized energy efficiency tailored to their unique needs, along with futureproofing through automatic upgrades and replacements. PaaS not only simplifies energy management but also contributes to a greener community through sustainable practices, all supported by dedicated maintenance and support services. This model appeals to a wide range of customers, including residential communities, commercial entities, and public infrastructure, by offering economic viability, direct energy cost reductions, and enhanced real estate value.

Value proposition

The PaaS business model for multi-use iGFBs offers a comprehensive solution that addresses the diverse needs of various stakeholders by providing access to advanced energy systems without the burden of ownership. The primary advantages offered to customers include:

Optimized Energy Efficiency: Multi-use iGFBs equipped with cutting-edge energy systems minimize waste and maximize efficiency. This is crucial for residential consumers facing high costs for energy efficiency updates and commercial entities needing to justify long-term savings.

Tailored Technological Integration: Services are customized to align with the unique architectural and environmental aspects of each building, catering to residential, commercial, and public sector stakeholders.

Futureproofing: PaaS ensures that energy assets remain state-of-the-art through automatic upgrades and replacements, providing a long-term, future-proof investment.

Sustainability as a Service: By adopting PaaS, customers outsource their sustainability goals to experts, ensuring contribution to a greener community, which is essential for regulators and policy makers striving for equitable access to energy benefits.

Dedicated Support and Management: The model includes regular maintenance, troubleshooting, and customer support, reducing the administrative burden on consumers.

Customers of the PaaS model include residential communities seeking energy efficiency, commercial entities aiming for sustainable energy management, public sector stakeholders with limited funding, agricultural sectors needing flexible energy solutions and energy entrepreneurs exploring renewable energy ventures without the need for extensive operational expertise and capital. Services are offered through integrated digital and physical platforms, adaptive service agreements, proactive energy asset management, and personalized energy consulting. Customers should pay for these services due to the economic viability, direct energy cost reductions, societal and environmental contributions, and enhanced real estate value.

The service is offered through a digital energy management platform paired with on-the-ground services for installation, maintenance, and optimization of energy assets. This enables to generate adaptive Service Agreements that evolves with changing customers' needs, accommodating new technologies or energy requirements without renegotiation. In this way, it is possible to build a proactive energy asset management while maintaining a personalised energy consulting experience to the user.

Customers are expected to pay for these services as they enhance the economic viability of their business, converting capital expenditure into operational expenditure, which is an interesting option for business with constrained budgets. These services aim to achieve economic viability through direct energy cost reduction, which further exacerbates the previous statement. In addition, these services contribute to build an environmentally conscious image for the customers with precise and comprehensive measure that will at the end increase the real estate value of the property.

SWOT Analysis

In this model, upfront costs are borne by the service provider, including the procurement of technology, which reduced the financial burden on customers and enables them to benefit from advanced technologies without significant investment. In this sense, customers experience predictable operational expenditures, improved cash flow management and enhanced energy efficiency leading to significant long-term savings for instant high efficiency head pumps provided a service substantially lower electric electricity bill.

Nevertheless, as any other business model, PaaS for multi-use iGFBs is subject to risks when deploying it. Stakeholders might experience market risks, as customers might be reluctance to relinquish control over energy assets, and even if achieved, there might be other operational risks due to the sophistication of the control systems. This require accurately demonstrate the technology through agents with great expertise in the solutions. The appearance of services disruptions might impact on the service's provider reputation.

The PaaS business model for multi-use iGFBs leverages its strengths in providing advanced, cost-effective, and sustainable energy solutions without upfront costs. It addresses the predictable operational expenditures and contributes to environmental sustainability, appealing to a broad customer base. However, weaknesses such as customer reluctance to cede control, operational complexity, and financial risks for the provider must be managed carefully. Opportunities abound with increasing demand for green energy solutions and technological advancements, while regulatory incentives further support the model's growth. Threats include regulatory changes, technological obsolescence, and potential reputation risks, which require proactive management and adaptive strategies to mitigate. This SWOT analysis is summarised in FIGURE 17:

	Helpful	**Harmful**
Internal Origin	**Strengths**	**Weaknesses**
	Access to advanced energy systems without upfront costs. Predictable operational expenditures. Contribution to a greener community.	Reluctance to relinquish control over energy assets. Operational complexity in managing diverse energy products. Financial risk for the service provider.
External Origin	**Opportunities**	**Threats**
	Growing market demand for sustainable energy solutions. Technological advancements enhancing service capabilities. Favourable regulatory incentives for renewable energy adoption.	Regulatory changes impacting financial viability. Rapid technological obsolescence requiring frequent upgrades. Reputation risks due to service interruptions or failures.

FIGURE 17. SWOT MATRIX FOR THE PRODUCT AS A SERVICE BUSINESS MODEL - MULTI USE IGFBS

Lean Model Canvas

The Lean Model Canvas outlines a clear strategy for deploying the PaaS business model for multi-use iGFBs. It addresses key problems faced by stakeholders, such as high initial costs and operational disruptions, by offering advanced energy systems and services without the burden of ownership. The solutions provided include proactive maintenance, flexible financing, and tailored integration, enhancing energy efficiency and sustainability. Key metrics focus on customer satisfaction, energy savings, and environmental impact, while the value proposition emphasizes optimized energy management and dedicated support. Channels include a digital platform and on-the-ground services, targeting customer segments such as residential communities, commercial entities, and public sector stakeholders. The cost structure involves procurement, operational expenses, and marketing, while revenue streams are generated through service agreements, energy trading, and asset upgrades. This comprehensive approach ensures that the PaaS model effectively meets the needs of diverse stakeholders, promoting sustainable and efficient energy solutions. This is summarised by FIGURE 18.

Problems	Solutions	Value Proposition	Advantage	Customer Segments
High costs of energy efficiency updates Operational disruptions during system upgrades Limited funding for public sector energy project	Access to advanced energy systems without upfront costs. Proactive maintenance and automatic upgrades. Flexible financing options to overcome financial barriers.	Optimized energy efficiency Tailored integration Futureproofing Sustainability Dedicated support	Eliminates the burden of the ownership Eliminates high initial costs Offer state-of-the-art energy solutions and support	Residential communities Commercial entities Public sector stakeholders
Existing Alternatives	**Key metrics**	**High-Level Concept**	**Channels**	**Early Adopters**
Traditional ownership models In-house energy management Conventional financing	Customer satisfaction and retention rates. Energy cost savings achieved. Reduction in carbon footprint and environmental impact.	Sustainable and efficient energy management as a service	Digital energy management platform. On-the-ground services for installation and maintenance. Adaptive service agreements and personalized consulting.	Environmentally conscious homeowners Businesses prioritizing sustainability Institutions seeking to reduce energy costs

Cost structure	Revenue Streams
Procurement of energy systems and technologies Operational and maintenance expenses Technology deployment and marketing costs Regulatory compliance and audits	Service agreements and subscriptions: monthly or annual Energy management plan consultation Energy trading and savings from efficiency improvements Upgrades and replacements of energy assets

FIGURE 18. LEAN MODEL CANVAS FOR MULTI-USE IGFBS – PRODUCT AS A SERVICE

3.3.3. Innovative Financing Schemes

This model facilitates the deployment of renewable energy solutions and energy-efficient technologies by providing accessible financing options, shared investment risks, and aligned incentives for various stakeholders. It leverages a combination of innovative financing mechanisms, such as OBF, PACE; PAYS models, and crowdfunding, to overcome financial barriers and promote sustainable energy adoption. Through customized financial products, partnerships with financial institutions, and community-based financing approaches, the IFS concept aims to make renewable energy solutions financially feasible and attractive to homeowners, small and medium-sized businesses, municipalities, investor groups, and low-income households.

Value Proposition

The value proposition for IFS in multi-use iGFBs is centred on making renewable energy and energy-efficient technologies financially accessible to a diverse range of stakeholders. This proposition addresses the high initial costs associated with energy efficiency upgrades, enabling residential consumers, commercial entities, and public sector stakeholders to invest in sustainable energy solutions without significant upfront financial burdens.

For residential customers, IFS provides a means to adopt advanced energy systems, alleviating concerns about integration and reliability by distributing costs over time and tying repayments to energy savings. Commercial entities benefit from minimal disruption to operations, as these financing models allow for phased upgrades and maintenance, justifying investments through demonstrable long-term savings. Public sector stakeholders gain the ability to implement large-scale energy projects within budget constraints, enhancing public perception and compliance with energy policies.

IFS is offered through customized financial products tailored to the needs of different customer segments, integration with digital platforms for transparent monitoring, strategic partnerships with financial institutions, and community-based financing approaches like crowdfunding. Customers are incentivized to pay for these services due to immediate economic benefits, long-term savings, enhanced energy resilience, and the alignment of financial and environmental goals.

SWOT Analysis

These schemes facilitate the adaptation to efficiency and regulatory changes by allowing for retrofit financing that includes future upgrades, such as incorporating new solar PV technology or advanced heat pump systems. Financial schemes can also adapt to market conditions, aligning repayments with actual energy savings, providing financial resilience against market volatility. The benefits include improved cash flow, enhanced energy infrastructure, and increased property values.

However, there are risks associated with deploying these business models. Market risks include potential lack of appeal due to customer distrust or lack of understanding of new financing mechanisms. Operational risks involve the need for specialized management expertise to administer these schemes effectively. Financial risks encompass the possibility of default, impacting the community's creditworthiness. Regulatory risks include changes in energy or financial regulations that could affect the viability of these schemes, while reputation risks stem from potential mismanagement or failure to deliver promised energy savings.

The SWOT analysis reveals that innovative financing schemes for multi-use iGFBs have significant strengths in providing accessible financing, sharing investment risks, and aligning incentives across stakeholders. However, weaknesses such as customer mistrust, administrative complexity, and default risks pose challenges. Opportunities arise from increasing market demand, technological advancements, and supportive regulatory environments. Yet, threats like regulatory changes, financial risks, and potential reputation damage must be carefully managed to ensure the sustainability and success of these financing models. This is summarised by FIGURE 19:

	Helpful	Harmful
	Strengths	**Weaknesses**
Internal Origin	Accessible Financing Options Shared Investment Risks Aligned Incentives	Lack of Understanding or Trust Complexity in Administration Default Risks
	Opportunities	**Threats**
External Origin	Growing Market Demand Technological Advancements Regulatory Support	Regulatory Changes Default and Financial Risks Reputation Risks

FIGURE 19. SWOT MATRIX FOR THE PRODUCT AS A SERVICE BUSINESS MODEL - MULTI USE IGFBS.

Lean Model Canvas

At its core, the Lean Model Canvas highlights the core aspects of the innovative financing schemes for multi-use iGFBs. By addressing the high initial costs and complexities of integrating energy-efficient technologies, these schemes provide accessible financing options that lower entry barriers. The value proposition lies in making sustainable energy financially viable through shared investment risks and aligned incentives. Key activities include developing tailored financial products, leveraging digital platforms, and forming strategic partnerships. Revenue is generated through interest payments, service fees, and transaction fees, ensuring the financial sustainability of these schemes. This is further summarised in FIGURE 20.

Problems	Solutions	Value Proposition	Advantage	Customer Segments
High initial costs for energy efficiency upgrades Integration and maintenance complexities Operational disruptions and regulatory compliance Limited funding for large-scale projects	On-bill financing PACE programs Pay-as-you save models Crowdfunding financing Community-based financing	Accessible financing for renewable energy solutions Shared investment risks and aligned incentives Financial feasibility for diverse customers segments Technological integration of cutting-edge releases	Lowering entry barriers for energy-efficient technologies Accessible Financing Options Regulatory support	Homeowners SMBs Municipalities Investors groups Low-income households
Existing Alternatives	**Key metrics**	**High-Level Concept**	**Channels**	**Early Adopters**
Traditional loans and grants Government subsidies	Adoption rate of financing schemes Energy savings achieved Customer satisfaction and retention rates	Making sustainable energy financially viable and attractive	Digital energy management platforms Partnerships with financial institutions Community outreach and education	Environmentally conscious homeowners Innovative businesses
Cost structure				**Revenue Streams**
Administrative setup and management costs Hardware and Software costs Marketing and regulatory compliance: energy audits Partnership fees, staff, financial interest				Interest Payments on Financing Services fees per financial consultation Transaction fees for digital platforms

FIGURE 20. BUSINESS MODEL CANVAS FOR MULTI-USE IGFBS - INNOVATIVE FINANCIAL SCHEMES

3.3.4. New Revenue Models

The NRM business model for multi-use iGFBs revolves around leveraging grid interaction capabilities to generate revenue streams for building owners while contributing to grid stability and environmental sustainability. These models enable building owners to monetize energy efficiency improvements, participate in energy markets, and enhance property values through smart and sustainable building certifications.

Value Proposition

The value proposition of NRM for multi-use iGFBs centres on leveraging advanced grid interaction capabilities to create additional revenue streams for building owners while enhancing grid stability and environmental sustainability.

Advantages Offered to Customers:

Pay-for-Performance: Customers benefit from models that directly tie payments to measurable energy efficiency and savings. This ensures that customers only pay for tangible improvements, offering clear value for money.

Flexibility Services: By integrating smart grid-ready systems, customers can offer ancillary services such as demand response and energy storage to the grid, thereby creating new revenue streams. This flexibility allows customers to optimize their energy usage and monetize excess capacity.

Increased Property Value: Smart, energy-efficient buildings often command higher rents or sales prices, providing a financial incentive for property owners to invest in advanced energy technologies.

Performance Certifications: Buildings with integrated smart energy systems can achieve high-performance certifications, enhancing their market value and attracting premium tenants and buyers.

Energy Trading Platforms: Participation in local energy markets or peer-to-peer trading platforms allows customers to sell excess energy, thus optimizing asset utilization and creating an additional revenue source.

Target Customers:

Property Owners and Developers: Seeking to increase the value of their investments through smart and sustainable building certifications.

Energy-Conscious Consumers: Interested in actively participating in energy markets and gaining financial rewards for their contributions to grid stability.

Businesses with Flexible Energy Demands: Able to adjust their energy usage in response to grid demands and capitalize on financial incentives.

Renewable Energy Advocates: Customers and investors looking to promote renewable energy adoption and engage in new market mechanisms.

Public Sector Stakeholders: Municipalities, educational institutions, and other public entities aiming to fund sustainability initiatives through new revenue streams.

The service will be offered through smart energy contracts, leveraging digital technologies such as AI and blockchain for transparent and efficient management of energy assets and transactions. User-friendly interfaces will enable customers to monitor, manage, and capitalize on their participation in new revenue streams.

Customers should pay for these services due to the direct financial returns from grid services and energy trading, the potential for increased property values through enhanced energy efficiency, and the societal benefits of contributing to a stable and sustainable energy system. Additionally, staying ahead of regulatory changes provides access to incentives and avoids penalties.

The integration of new revenue models into multi-use iGFBs requires careful consideration of stakeholder problems, cost-benefit analysis, and potential risks.

This Business Model is trying to solve the following problems of the stakeholders:

Residential Customers: High initial costs and complexity in system integration are significant challenges. Offering financing schemes and user-friendly management platforms can mitigate these issues.

Commercial Entities: Operational disruptions and the need for long-term investment justification are key concerns. Providing performance guarantees and phased implementation strategies can address these.

Public Sector Stakeholders: Limited funding and regulatory compliance challenges can be addressed through innovative financing schemes and demonstrating clear regulatory benefits.

SWOT Analysis

To solve the problems faced by the previous stakeholders the service provider of the multi-use iGFBs face high setup costs for real-time data transmission and market participation in new revenue schemes, which might greatly differ from previous experiences.

Nevertheless, they will directly benefit from revenue generation from participating in energy markets, increased property values due to smart certifications, and improved energy independence and sustainability. As any other Business Model, there are several noteworthy risks that should be tackled:

Market Risks: Revenue dependency on fluctuating energy markets can impact financial stability. Mitigation strategies include diversified revenue streams and conservative financial projections.

Operational Risks: The complexity of implementing and managing integrated systems requires specialized expertise. Continuous training and robust system design can minimize these risks.

Financial Risks: High initial capital investment may not yield expected returns. Careful planning and phased investments can reduce financial exposure.

Regulatory and Compliance Risks: Changes in energy policy could affect model viability. Continuous monitoring and proactive engagement with regulators are essential.

Reputation Risks: Mismanagement or underperformance can harm reputations. Maintaining transparency and rigorous performance monitoring is crucial.

The SWOT analysis highlights the robust potential of new revenue models for multi-use iGFBs, emphasizing strengths such as the pay-for-performance model, flexibility in grid services, and increased property value through certifications. However, challenges such as market dependency, complexity in implementation, and financial risks must be carefully managed. Opportunities abound in growing market demand and technological advancements, while threats from market volatility, operational challenges, and regulatory changes necessitate vigilant management and adaptation. By leveraging strengths and opportunities while addressing weaknesses and threats, stakeholders can optimize the deployment and success of these models. This is depicted by FIGURE 21.

	Helpful	**Harmful**
	Strengths	**Weaknesses**
Internal Origin	Pay-for-Performance Model ensures value for money. Flexibility in offering ancillary grid services. Increased property value and certifications.	Dependency on fluctuating energy markets. Complexity in implementation and management. Financial risk associated with initial investment.
	Opportunities	**Threats**
External Origin	Growing market demand for grid services. Advancements in technology for efficient operations.	Market volatility impacting revenue streams.

	Regulatory incentives for renewable energy adoption.	Operational challenges in system management.

FIGURE 21. SWOT MATRIX FOR NEW REVENUE MODELS – MULTI USE IGFBS

Lean Model Canvas

The Lean Model Canvas for new revenue models in multi-use iGFBs outlines a strategic approach to address the high costs and complexity of energy efficiency upgrades through innovative financing schemes, smart contracts, and user-friendly platforms. Key metrics focus on energy savings, revenue generation, and customer satisfaction, reinforcing the value proposition of monetizing energy efficiency and grid services. The models leverage technological integration and regulatory alignment to provide direct financial returns, increased property values, and contribute to environmental sustainability. Channels include smart energy contracts and technology-driven solutions, targeting property owners, energy-conscious consumers, and flexible energy businesses as primary customer segments. Initial setup and operational costs are offset by diverse revenue streams, ensuring long-term financial viability amidst potential operational and market risks. This comprehensive approach aims to optimize the deployment and success of multi-use iGFBs, addressing stakeholder challenges and maximizing benefits. This can be seen in FIGURE 22:

Problems	Solutions	Value Proposition	Advantage	Customer Segments
High costs and complexity of energy efficiency upgrades Justifying long-term investment for commercial entities Limited funding for public sector energy projects	Pay-as-you-save Crowdfunding Smart contract and performance-based models User-friendly energy management platforms	Pay-for-performance Flexibility services Increased property value Performance certifications Energy trading platforms	Direct financial returns Increased property values. Technological integration Regulatory alignment. Contribution to societal and environmental sustainability	Property owners Developers Energy-conscious consumers. Businesses with flexible energy demands.
Existing Alternatives	**Key metrics**	**High-Level Concept**	**Channels**	**Early Adopters**
Traditional HVAC systems, standard building materials Basic energy audits, regulatory compliance Government grant, traditional loans	Energy savings achieved. Revenue generated from grid services. Customer satisfaction and engagement levels.	Monetizing energy efficiency and smart grid interactions for sustainable and financially viable buildings	Smart energy contracts. Technology-driven solutions (AI, blockchain). User-friendly interfaces.	Renewable energy advocates Public sector stakeholders

Cost structure	Revenue Streams
Initial Setup costs for infrastructure Operational costs for system management Maintenance and upgrade costs Regulatory compliance and energy audits	Participation in Energy markets and Grid Services provision Property value increase and certification Energy Trading Platform fees

FIGURE 22. BUSINESS MODEL CANVAS FOR MULTI-USE IGFBS - NEW REVENUE MODELS

3.4. Summary of the key findings

Section 3.1.1 provides an overview of **existing revenue opportunities** for iGFBs across Europe. It emphasizes understanding regional regulatory frameworks and market dynamics, highlighting models like RECs in Spain, cooperative energy communities in Greece, and VPPs in Luxembourg. The section also covers initiatives in sustainable mobility hubs in Belgium and industrial energy services in Portugal and Germany. Regulatory assessments reveal challenges such as fragmented regulations in Belgium, slow incentive implementation in Croatia, and grid capacity issues in Luxembourg and Portugal. Despite challenges, Spain demonstrates progress with smart meter deployment and renewable energy goals.

Section 3.2 explores potential future business models for **single-use iGFBs** under the WeForming project, focusing on functionalities like *thermal storage optimization, solar PV self-consumption, and flexibility in balancing markets*. It evaluates models such as One Stop Shop, Product as a Service, Innovative Financing Schemes and New Revenue Models, highlighting their alignment with EU energy policies. The key findings of these business models rely on the focus of providing access to advanced energy technologies, such as, cloud optimisation for enhanced energy management of the active assets of the building while providing enhanced grid stability thorugh grid forming capabilities of the products installed. In this sense, financing schemes might varies across the different types of models, but schemes such as on-bill financing and performance contracting have potential for ensure return on investment of these novel energy solutions.

In Section3.4 3.2.4, potential future business models for **multi-use iGFBs** integrate diverse energy functions like electrical and thermal optimization within the same energy hub. Business models like OSS and PaaS aim to simplify energy transitions in such complex systems by offering centralized solutions or access to advanced energy systems without upfront payments, respectively. IFS aim to overcome financial barriers through mechanisms like On-Bill Financing (OBF) and crowdfunding, catering to homeowners, businesses, municipalities, investor groups, and low-income households. NRM focus on monetizing energy efficiency improvements through pay-for-performance models and ancillary services, facing challenges such as market dependency and regulatory changes that might jeopardise their wide adoption.

4. Functional specifications for interoperability and standardised data integration between iGFBs and their energy eco-system

4.1. Introduction to Interoperability Needs

Interoperability across various technological platforms, especially in the context of modern energy systems, is critical for achieving efficient and sustainable energy management. The seamless exchange and functional compatibility of data across different systems, facilitated by standardized communications, serve as a backbone for dynamic market environments featuring diverse technological ecosystems. This section aims to analyze the necessity and drivers of interoperability from a scientific perspective, delving into market demands, challenges in standardization, and methodologies adopted by standardization bodies like the European Telecommunications Standards Institute (ETSI).

4.1.1. Importance of Interoperability

Interoperability serves as a fundamental facilitator of seamless communication and effective collaboration among various components in energy systems. This includes consumer interfaces, distributed energy resources (DERs), and large-scale utility plants. It provides the technological foundation necessary for the development of advanced, efficient, and dependable energy management systems. Interoperability is integral to achieving the sustainability targets outlined in international energy policies, ensuring that energy systems can adapt and integrate with future technologies and energy demands seamlessly.

Market Drivers for Interoperability

The push for interoperability is primarily driven by the need to enable a diverse range of energy systems components to interact within a multi-vendor, multi-network, and multi-service environment. This need is becoming increasingly critical as the global push towards renewable energy sources and smarter energy grids gathers momentum. By facilitating interoperability, we ensure a broader adoption of technologies, thus leveraging economies of scale that benefit both consumers and manufacturers. In a world where the Internet of Things (IoT) and Machine-to-Machine (M2M) communications are expanding rapidly, the ability to integrate and communicate across various platforms and standards is essential, thereby enhancing the robustness and functionality of energy systems.

From ETSI Strategic Objectives of Interoperability to WeForming

Optimal Resource Utilization: Interoperability enables various energy assets to communicate and operate collaboratively, which is crucial for the optimal allocation and efficient use of resources. This collaborative operation helps minimize waste and reduce operational costs, making energy systems more efficient and less environmentally taxing. In WeForming, standardized data integration protocols will enhance the capability of iGFBs to engage in real-time resource optimization, thereby reducing inefficiencies across the energy network.

Enhanced Grid Stability and Reliability: Through interoperability, energy systems can achieve dynamic load balancing and real-time management of supply and demand fluctuations. This not only enhances the overall grid reliability but also fortifies the grid’s resilience against disturbances and unexpected changes in energy supply or demand. The development of functional specifications in WeForming will enable improved predictive analytics and real-time data flows, crucial for maintaining grid stability amid variable energy supplies.

Facilitation of Renewable Energy Integration: As the world moves towards a more sustainable energy mix, interoperability plays a critical role in integrating renewable energy sources with traditional power grids. It ensures that the inherently variable outputs from renewable sources are managed and integrated effectively, maintaining grid stability and energy reliability. WeForming will focus on creating data exchange standards that facilitate quicker and more efficient integration of renewable energy sources into existing grid infrastructures, supporting sustainable energy goals.

Regulatory Compliance and Innovation Support: Interoperable systems are better positioned to comply with evolving regulatory frameworks that focus on emissions, energy efficiency, and sustainability. Furthermore, interoperability encourages an ecosystem ripe for technological innovations and the development of new business models, thus enhancing consumer choices and market competitiveness.

ETSI's Role in Promoting Interoperability

The European Telecommunications Standards Institute (ETSI) is instrumental in the development and implementation of interoperability standards. ETSI's methodologies include testing and validation procedures, such as Plugtests™, which are critical for verifying the practical application and effectiveness of these standards. These validation activities help identify areas for enhancement, ensuring that standards are continually adapted to meet the evolving needs of the industry. By defining interoperability standards, WeForming will simplify compliance with regulatory requirements and foster an environment conducive to innovation and the development of advanced energy management solutions.

4.1.2. Standardization of Data Exchange

The quest for interoperability within energy systems hinges critically on the standardization of data exchange. This entails developing and enforcing universally accepted data formats and protocols to ensure seamless communication and interaction across diverse systems. Such standardization is pivotal for managing the complexities inherent in modern energy systems, thus facilitating effective optimization and control. This discussion provides an in-depth analysis of the pivotal data standards that underpin this interoperability, examines the multifaceted benefits of standardized data exchange, and projects the implications for future developments within the sector.

Achieving efficient data exchange across energy systems demands a foundation of robust, universally recognized data standards. These standards address the interoperability needs across various platforms and devices, an essential feature as energy networks evolve. Two critical standards that have become cornerstones in the architecture of energy systems include:

- **SAREF4ENER (Smart Appliances REFerence ontology for Energy)**: This ontology, part of the SAREF initiative launched by the European Commission, is instrumental in enabling energy-related devices to communicate effectively across different energy management systems. By offering a coherent ontology, SAREF4ENER ensures that smart devices from various manufacturers can interact seamlessly, thereby enhancing system efficiency and integration capabilities.
- **Energy Market Standard Profiles (ESMP-62325-X)**: Developed under the IEC 62325 framework, this suite of standards is tailored specifically for the electricity market's data exchange requirements. It standardizes communication protocols for crucial market operations such as energy bidding and real-time pricing, ensuring transparency, efficiency, and security in market transactions. These standards are fundamental in facilitating a smoother integration of market operations and improving overall operational reliability.

Expanding on the Benefits of Standardized Data Exchange

The adoption of standardized protocols across energy systems confers several strategic advantages:

- **Scalability**: Standardized data protocols are essential for the seamless expansion of energy systems, accommodating new components and technologies without compromising existing frameworks. This flexibility is crucial for adapting to the dynamic needs of modern energy grids, including integrating fluctuating renewable energy outputs and distributed energy resources.
- **Integration Efficiency**: By standardizing communication protocols, different systems and devices—often from disparate manufacturers—can be interconnected with minimal need for customization. This not only simplifies technology deployment but also significantly reduces associated costs and complexities.
- **Streamlined Maintenance and Upgrades**: Systems constructed around common data standards facilitate easier support and updates, decreasing total ownership costs and enhancing the longevity and functionality of energy infrastructures.
- **Robust Security**: Integral to standard data protocols are advanced security features that protect against unauthorized access and data breaches, a non-negotiable in the energy sector given the potential ramifications of security failures on infrastructure and privacy.

Through the implementation of these data standards, energy systems are equipped not only to address current operational challenges but also to lay a solid foundation for future technological enhancements and system integrations. The strategic application of these standardized protocols is critical in steering the continuous development of energy systems, pushing them toward enhanced efficiency, bolstered security, and increased sustainability. This proactive approach in standardizing data exchange significantly propels the energy sector forward, preparing it to meet emerging demands and capitalize on new technological opportunities.

Integration Technologies and Functional Requirements

The evolution of the energy sector towards a decentralized and digitalized model mandates sophisticated integration technologies to effectively connect Integrated Green Forming Buildings (iGFBs) with the wider energy ecosystem. This section expounds on advanced integration solutions, architectural models, and data integration specifications that are critical to achieving high levels of interoperability, ensuring that iGFBs can act as proactive nodes within the smart grid.

Integration Solutions and Architectural Models

In addressing the complex dynamics of variable energy sources and the fluctuating demands of modern energy consumers, iGFBs require robust integration solutions that are capable of handling real-time data processing and ensuring comprehensive system security.

Specific Integration Technologies

- **Microgrid Controllers and Intelligent Electronic Devices (IEDs):**
    - **Function:** These devices are pivotal in managing energy flows within iGFBs, adjusting in real-time to changes in energy production and consumption. These devices will act as the real-time controllers within the WeForming framework, integrating with AI/ML energy services to enhance predictive operations and system efficiency.
    - **Communication Standards:** They utilize protocols such as IEC 61850, which are essential for the seamless integration of renewable energy sources and ensuring interoperability across different energy management systems.
- **Building Energy Management Systems (BEMS):**
    - **Role:** BEMS optimize energy usage within buildings by managing HVAC, lighting, and other energy-intensive systems. BEMS will be integrated with WeForming's market platforms, utilizing cloud-based analytics and AI/ML to optimize energy usage and operational efficiency.
    - **Integration Protocols:** BEMS often employ BACnet for internal operations and may integrate with broader smart grid protocols like IEC 61850 to interact with external energy systems.

- **Edge Computing Platforms:**
    - **Importance:** By processing data locally at or near the source of data generation, edge computing platforms reduce response times and bandwidth usage. These platforms will be enhanced with AI algorithms and machine learning from WeForming to provide advanced decision-making capabilities.
    - **Implementation:** These platforms handle data from IoT devices distributed throughout the buildings, managing local energy generation and storage to optimize efficiency and response to grid conditions.
    - **Relevant Protocols:** The implementation of edge computing in building management systems typically involves the use of protocols such as MQTT (Message Queuing Telemetry Transport) and CoAP (Constrained Application Protocol). These protocols are well-suited for the low-power and limited bandwidth environments that characterize many IoT and edge computing scenarios. MQTT is particularly valued for its lightweight publish/subscribe messaging system, which is ideal for the sporadic data flows in IoT applications. CoAP, designed specifically for the needs of electronic devices, is another protocol that enables simple, constrained devices to communicate interactively over the Internet.

Architectural Models

The architecture of energy management systems is pivotal in defining how energy data is processed, stored, and utilized across different environments. These architectural decisions not only influence the system's efficiency and scalability but also determine its ability to meet security and regulatory requirements. With the evolution of technology, various architectural options have emerged, each presenting unique advantages and challenges. Below, we explore two prevalent models — Hybrid Cloud and On-Premise Systems, and Distributed Ledger Technologies (DLT) — to understand their configurations, applications, and the specific roles they play within the context of Integrated Green Forming Buildings (iGFBs).

- **Hybrid Cloud and On-Premise Systems:**
    - **Configuration:** This model combines the extensive data processing capabilities of cloud computing with the security and immediate responsiveness of on-premise systems, providing a scalable solution for data management. This model will leverage WeForming's cloud platforms for extensive data analytics and predictive maintenance, aligning cloud capabilities with local data processing needs.
    - **Applications:** Ideal for performing extensive data analytics, supporting predictive maintenance, and optimizing energy usage without compromising data security.
- **Distributed Ledger Technologies (DLT):**
    - **Usage:** Blockchain and other DLTs are employed within iGFBs to log energy transactions securely and transparently. These technologies are critical for automating transactions in decentralized energy trading. WeForming will utilize DLTs to facilitate secure and transparent energy transactions within its market platforms, supporting decentralized energy trading.
    - **Benefits:** Enhance the reliability of peer-to-peer energy exchanges by providing a secure, transparent, and verifiable platform, crucial for iGFBs that engage in energy trading or sell excess energy back to the grid.

Data Integration Specifications

For iGFBs to function effectively within the broader smart grid, precise and robust specifications for data formats, APIs, and interfaces are essential. These specifications must cater to seamless integration and maintain interoperability across various platforms and devices.

In the field of industrial and intelligent energy systems, a variety of communication protocols play pivotal roles, each aligning with specific layers of the OSI model to ensure reliable, high-speed, and efficient data transmission. Those protocols are:

- **Ethernet/IP:** Used primarily at the Data Link Layer (Layer 2) and the Network Layer (Layer 3), Ethernet/IP is crucial for setting up reliable, high-speed connections between devices in industrial environments, including those within smart energy systems.
- **ZigBee and Z-Wave:** These are primarily used in home automation and are applicable at the Network Layer (Layer 3). They provide a mesh network communication protocol that is highly efficient in environments with numerous small devices, making them suitable for residential iGFBs.
- **Modbus:** Commonly utilized at the Application Layer (Layer 7), Modbus is a serial communication protocol that serves as a standard for connecting industrial electronic devices and for allowing communication between many devices connected to the same network, often used in older systems that require a simple, robust, and easy-to-use communication protocol.
- **DNP3 (Distributed Network Protocol):** Operating at the Application Layer (Layer 7), DNP3 is a set of communications protocols used between components in process automation systems. It is extensively used in utilities and is particularly strong in communication between various types of data acquisition and control equipment.
- **LoRaWAN:** This protocol operates primarily at the Network Layer (Layer 3) and is used for long-range communications. Ideal for smart city applications, it supports low-power operations for wide-area network communications, which is essential for smart grid applications that cover broad geographic areas.

Advanced Data Formats and Protocols

- **IEC 61968/61970 (Common Information Model - CIM):**
  - **Function:** Facilitates the standardization of electrical data exchange across generation, transmission, and distribution, supporting complex interactions like demand response and distributed energy resource management.
  - **Benefits:** Ensures that iGFBs can participate fully in modern smart grid environments, responding dynamically to changes in grid conditions and operational demands.
  - **Layer:** Application (Layer 7 of the OSI Model)
- **MQTT and CoAP for IoT Communications:**
  - **Description:** These lightweight messaging protocols are optimized for the limited power and bandwidth conditions typical of IoT devices used within smart buildings.
  - **Role:** Critical for ensuring reliable and timely communication between IoT devices and central energy management systems.
  - **Layer:** Session (Layer 5 of the OSI Model) and Transport (Layer 4)

APIs and Interface Standards

- **RESTful APIs and WebSockets:**
  - **Functionality:** Facilitate straightforward, flexible integration with web services and provide real-time, two-way communication between iGFBs and central energy management systems.
  - **Advantages:** Essential for continuous and interactive data exchanges, supporting responsive and adaptive energy management strategies.
  - **Layer:** Application (Layer 7 of the OSI Model)

- **OPC UA for Cross-Platform Interoperability:**
    - **Purpose:** Ensures secure and reliable data exchange between diverse systems and devices, which is vital for maintaining interoperability in industrial automation settings, including those within iGFBs.
    - **Integration:** Allows devices from different manufacturers to communicate effectively, maintaining a consistent operational environment across the energy sector.
    - **Layer :** Application (Layer 7)

The integration of advanced technologies and detailed specifications plays a crucial role in enabling intelligent grid forming buildings (iGFBs) to attain exceptional levels of efficiency, sustainability, and operational flexibility. Leveraging these specified standards and models allows iGFBs to seamlessly interact within the expansive smart grid infrastructure. This interoperability supports both present and future energy management strategies, ensuring that iGFBs not only optimize their internal energy use but also contribute significantly to the broader goals of energy systems. By adhering to well-defined standards and protocols, iGFBs enhance their ability to adapt to dynamic energy demands and supply conditions. This adaptability is pivotal for maintaining the balance and reliability of the smart grid, particularly as the energy landscape evolves with the increasing integration of renewable energy sources. Detailed specifications ensure that all components within iGFBs, from distributed energy resources (DERs) to building energy management systems (BEMS), operate harmoniously, fostering a cohesive energy ecosystem.

Moreover, the adoption of these advanced technologies facilitates real-time data exchange and precise control mechanisms, which are essential for proactive energy management and decision-making. iGFBs can thus respond swiftly to grid signals, participate in demand response programs, and optimize energy consumption patterns, thereby reducing operational costs and minimizing environmental impact. In essence, the commitment to integrating advanced technologies and adhering to detailed specifications positions iGFBs as pivotal players in the smart grid infrastructure. This strategic alignment not only enhances the resilience and adaptability of energy systems but also drives forward the global agenda for sustainable energy management.

4.2. Security, Compliance, and Implementation Strategies

4.2.1. Security Measures and Compliance

In the complex ecosystem of modern energy systems, interfaces serve as vital components that enable efficient communication across various platforms and technologies. These interfaces are fundamental to integrating disparate systems, allowing them to 'speak' the same language and exchange data seamlessly. By bridging different technologies, interfaces enhance the interoperability of systems, which is crucial for the dynamic and efficient operation of energy grids.

Function and Value of Interfaces

Strengthening System Security: Interfaces are essential in maintaining the security of diverse hardware and software within energy systems. They implement robust security protocols, such as encryption and authentication mechanisms, ensuring that data exchanged across systems remains protected from unauthorized access and cyber threats. This layer of security is crucial for preserving the integrity and confidentiality of data as it moves between systems with varying security standards.

Ensuring Reliable Communication in Adverse Conditions: Beyond facilitating seamless data flow, interfaces are designed to ensure reliable communication under potential security threats and adverse conditions. They utilize advanced security measures to detect and mitigate potential intrusions, ensuring continuous operation even when the system's security is at risk.

Compliance with Regulatory Security Standards: By adhering to stringent security standards and regulations, such as GDPR for data protection and NERC CIP for the energy sector, interfaces ensure that energy systems are not only interoperable but also compliant with global security norms. This adherence protects the systems against legal and operational risks and builds trust among stakeholders.

Supporting Proactive Security Management: Interfaces enable real-time monitoring and control of data flows, which is essential for proactive security management. This capability allows energy systems to rapidly respond to security alerts and adjust operations to prevent potential breaches, thereby enhancing overall system resilience.

Facilitating Secure Integration of Renewable Energy Sources: As the energy sector continues to incorporate renewable sources, interfaces play a critical role in securely integrating these new technologies. They ensure that data from renewable sources is securely communicated and integrated into the traditional power grid, safeguarding the entire energy management system from potential security vulnerabilities associated with new technology integrations.

The functionality of interfaces in energy data exchange is transformative, bridging gaps between diverse technologies and systems to enhance operational effectiveness and grid reliability. As the energy sector continues to evolve with the incorporation of more decentralized and renewable energy sources, the role of interfaces in ensuring seamless integration and communication becomes increasingly significant. This foundational role not only supports current operational needs but also paves the way for future advancements in energy management and grid modernization.

FIGURE 23 INTEGRATION STATEGIES FOR INTERFACES.

To enhance the formal and research-oriented documentation of the integration strategy for interface functionality in energy systems, the following roadmap provides a structured approach to implementing these critical components:

1. **Assessment and Planning**: The initial phase involves a thorough assessment of the existing energy systems infrastructure to identify current capabilities and pinpoint integration challenges. This assessment will map out the communication pathways and technology compatibilities within the existing setup, providing a detailed understanding of where enhancements are necessary.
2. **Standardization of Protocols**: Following the initial assessment, efforts will focus on the standardization of communication protocols and data formats. This stage is crucial for establishing a unified language across diverse systems, ensuring that data exchange is both seamless and consistent. The standardization process will adhere to international best practices and consider emerging trends in energy system management.
3. **Development and Integration**: With standardized protocols in place, the development of new interfaces or the refinement of existing ones will commence. This development phase aims to create robust interfaces capable of bridging any identified technological gaps. These interfaces

will facilitate effective communication between previously incompatible systems, enhancing overall system interoperability.

4. **Testing and Optimization**: Prior to full-scale deployment, the newly developed interfaces will undergo rigorous testing to validate their functionality and performance. This testing phase is critical to ensuring that the interfaces meet all specified requirements and operate reliably under various conditions. Based on testing outcomes, further optimizations may be performed to refine data handling and exchange processes.
5. **Deployment and Continuous Improvement**: The final stage involves deploying the interfaces across the energy network. This deployment will be systematically executed to minimize disruptions and ensure a smooth transition to the enhanced system. Post-deployment, a regime of continuous monitoring and periodic updates will be established. This ongoing improvement process is essential for adapting to technological advancements and evolving industry standards, thus maintaining the efficacy and sustainability of the energy systems.

In advancing the roadmap for interface functionality enhancement, WeForming will incorporate a methodical review of interface entries from previous projects. This step involves a detailed analysis of historical data to identify successful strategies and detect potential gaps. Following this review, WeForming will conduct a comprehensive gap assessment to pinpoint areas requiring improvement or modification in current interfaces. Additionally, pilot interactions will be initiated to test the efficacy of these interfaces in real-world scenarios. Insights gathered from these pilots will be instrumental in refining the WeForming Interface Catalogue, a central repository of standardized interface protocols. This integration of feedback from practical implementations and historical data ensures that development strategies are precisely tailored to meet the dynamic needs of the energy sector, enhancing the reliability and functionality of the interfaces

4.2.2. Implementation Challenges and Roadmap

In the evolving landscape of energy management, interfaces play a pivotal role in ensuring seamless data exchange across diverse systems and technologies. The architecture of these interfaces, encompassing various components from data flow mechanisms to security protocols, is foundational to achieving interoperability and operational efficiency in modern energy systems. This subsection explores the individual components that constitute these interfaces, elaborating on their functionalities and their impact on system performance based on contemporary research and industry practices. To provide a clear and comprehensive understanding, the table below concisely details each component, describing their functionalities and illustrating their critical impact on the overall performance and efficiency of energy management systems.

The detailed components of interfaces in energy data exchange are integral to crafting systems that are not only interoperable but also adaptable to the evolving demands of the energy sector. Through rigorous standardization, meticulous design, and strategic deployment of these components, energy systems can achieve enhanced efficiency, security, and compliance, paving the way for advanced energy management solutions.

TABLE 7. SCHEME FOR DESCRIBING INTERFACE COMPONENTS

Component	Description	Impact on System
Functionality	Describes the specific functions and operations of the component.	Enhances alignment with system requirements for better modular development.

Service Category	Identifies the service provided (e.g., transaction management).	Optimizes data flow and segmentation for performance enhancements.
Standards/Protocols	Lists the standards and protocols used (e.g., IEC 61850, MQTT).	Ensures interoperability and reliability across different systems.
Data Flow (Input/Output)	Outlines how data enters and exits the component.	Improves data handling strategies and operational efficiency.
Data Format	Specifies data formats used (e.g., JSON, XML).	Affects system compatibility and processing speed.
Frequency	Details the frequency of data exchanges.	Influences response times and system dynamics for stability.
Security Protocol	Describes security measures implemented (e.g., TLS, SSL).	Secures data integrity and confidentiality; essential for compliance.
Data Source and Destination	Identifies the origin and endpoints for data routing.	Reduces latency and improves efficiency in data transfers.
Integration Pattern	Describes the integration approach (e.g., synchronous, publish/subscribe).	Enhances system flexibility and scalability.
Business Object	Focuses on specific business objectives (e.g., energy consumption data).	Aligns interface operations with strategic business goals.
Compliance with EU Regulations	Ensures adherence to regulatory standards (e.g., GDPR).	Enhances consumer trust and supports legal compliance.
Demo/Use Case	Provides examples of practical applications and validations.	Demonstrates the component's applicability and effectiveness.
Technology Platform	Indicates the underlying technology platform (e.g., cloud-based).	Influences performance, reliability, and scalability of the interfaces.

4.2.3. Case studies

This section explores practical implementations of interfaces within the energy sector, demonstrating how innovative designs and strategic integrations enhance interoperability and streamline data exchange. Each case study reflects on the application of specific interface components, shedding light on how these implementations address unique industry challenges and contribute to the evolution of energy management systems.

Case Studies Overview

1. Gm-Hub-API (Gm-Hub01)

- **Functionality and Impact:** The Gm-Hub-API serves as a central hub for managing demand response and smart grid functionalities, linking various stakeholders like market players and DSOs. This interface efficiently handles real-time inputs of demand response requests and market data, outputting crucial data-driven services and strategic responses.
- **Technical Implementation:** Utilizing standards IEC 61968 and IEC 61970, and supporting JSON and XML data formats, this cloud-based interface operates under stringent security measures (TLS,

SSL) to ensure data integrity and compliance with GDPR. Its asynchronous, Publish/Subscribe integration pattern enhances scalability and responsiveness.
- **Outcome:** The deployment of Gm-Hub-API has led to more efficient demand response management across multiple DSOs, facilitating rapid adjustments to grid operations and enhancing the overall stability of energy distribution networks.

2. E-Flex-API (EFLEX02)

- **Functionality and Impact:** E-Flex-API enables dynamic interaction with aggregators to trade local flexibilities, improving the operation of distribution networks. It processes flexibility offers and activation requests, providing real-time updates on grid support and flexibility utilization.
- **Technical Implementation:** Operating on a server-based platform, this interface adheres to custom protocols developed to meet specific local DSO requirements. It utilizes XML for data formatting and SSL for security, functioning within a synchronous request/response integration pattern.
- **Outcome:** This interface has enhanced grid reliability in localized network areas, allowing DSOs to manage and respond to fluctuations in power supply and demand more effectively.

3. DCP-API (DCP03)

- **Functionality and Impact:** The DCP-API manages the planning and control of distributed heat-pumps, facilitating flexibility trading between grid-interactive buildings and local grid operators. It ensures the optimal operation of energy resources by processing real-time data from heat-pumps and demand signals.
- **Technical Implementation:** This hybrid interface uses MQTT for sensor communication and JSON for data formatting, secured by TLS protocols. It supports asynchronous, Publish/Subscribe patterns, ensuring timely and efficient data handling compliant with the NIS Directive.
- **Outcome:** Optimizing energy use in grid-interactive buildings, DCP-API has enabled more precise and effective management of distributed energy resources, reducing operational costs and enhancing system resilience.

4. Platone-API (PLATONE04)

- **Functionality and Impact:** Platone-API enhances network observability and manages the volatility of renewable energy sources by integrating various data layers and communication protocols. It processes inputs like renewable energy data and consumption patterns, delivering critical network management commands and flexibility actions.
- **Technical Implementation:** Leveraging blockchain-based security protocols for data integrity and privacy, this cloud-based interface operates in a hybrid (synchronous and asynchronous) pattern, supporting JSON and XML formats.
- **Outcome:** This API has significantly improved the integration of renewable energy into existing grid frameworks, facilitating enhanced energy management and contributing to sustainability goals aligned with EU energy policies.

These case studies demonstrate the practical application and benefits of advanced interface designs in real-world energy management scenarios. By integrating diverse data sources, managing complex data flows, and adhering to rigorous security and regulatory standards, these interfaces have significantly enhanced the interoperability and efficiency of energy systems. The ongoing improvements and adaptations in interface design not only respond to immediate operational challenges but also strategically position energy systems for future advancements, ensuring sustainability and resilience in the face of evolving energy demands.

5. WeForming Reference Architecture (RA) definition

A Reference Architecture for intelligent Grid-Forming Buildings (iGFBs), is a blueprint for building Data Spaces for iGFBs. It provides a standard framework for creating data-driven ecosystems, products, and services. It provides a template, often based on the generalization of a set of solutions. Furthermore, it shows how to compose these parts together into a solution. Adopting a reference architecture accelerates delivery through the re-use of an effective solution and provides a basis for governance to ensure the consistency and applicability of technology use.

Adopting a reference architecture leads to: (a) improvement of the interoperability of the software systems by establishing a standard solution and common mechanisms for information exchange; (b) reduction of the development costs of software projects through the reuse of common assets; (c) improvement of the communication because actors share the same architectural mindset; (d) influencing the learning curve of developers due to the need of learning its features; and (e) facilitates the development of a community/marketplace based on the harmonised approaches and standards.

Data Space Reference Architectures aim to facilitate secure and trusted data exchange in business ecosystems, supporting data-driven business models and the smart service world.

Subsection 5.1 provides a review of the actual ongoing architectures from Horizon projects of relevance: OPEN DEI, Interconnect, PlatONE, INTERRFACE, PLATOON and OneNET; as well as BRIDGE Data Exchange Reference Architecture. In addition, the document offers an examination of the architectural frameworks developed by prominent European Union initiatives, namely GAIA-X, FIWARE, AIOTI and IDSA recognized for their international impact.

Subsection 5.2 explores the rationale for implementing Data Spaces for intelligent Grid Forming Buildings (iGFBs). It emphasizes the evolving role of buildings within the power grid, transitioning from passive consumers to active participants capable of providing and storing energy. To achieve this enhanced Building-to-Grid service integration, the report underscores the importance of interoperable design facilitated by Data Spaces.

Subsection 5.3 highlights the advantages of Data Spaces to iGFB participants and the main business motivation. It facilitates secure data sharing while maintaining data sovereignty, allowing collaboration based on metadata without compromising the physical location of the data. This enables participation in inclusive Power Demand-Response programs and the creation of high-quality data and service catalogues. Ultimately, the iGFB Data Space fosters a business ecosystem for multi-energy systems, capitalizing on evolving European initiatives.

Subsection 5.3 outlines the first version of the Reference Architecture and provides a comprehensive summary of the functional requirements gathered from WeForming participants as well as the methodology followed by the project participants.

5.1. Analysis of relevant on-going Reference Architectures

5.1.1. Review of European Initiatives on Reference Architecture Models

5.1.1.1. Smart Grid Architecture Model (SGAM)

In fulfilment of the European Commission's standardization mandate M/490, three leading European Standardization Organizations (ESOs) collaborated to develop the Smart Grid Architecture Model (SGAM). A review of existing literature highlights the Smart Grid Architecture Model (SGAM), developed by the CEN-CENELEC-ETSI Smart Grid Coordination Group (SG-CG) in 2012, as a prominent choice for systematic smart grid architecture development (Panda & Das, 2021). This preference stems from SGAM's strengths in several key areas: clarity of use case management, visualization, explicit interoperability. The Smart Grid Architecture Model (SGAM) adopts a three-dimensional structure, visualized as a cube (see Figure 24 The smart grid architecture model (SGAM). This structure comprises five distinct interoperability layers: component, communication, information, function, and business. These layers effectively integrate Information and Communication Technologies (ICT), energy informatics, and business considerations within the framework of modern and future smart grid technologies. Each layer is further segmented into two axes: domains and. Domains encompass the entire energy conversion chain, spanning bulk generation, transmission, distribution, distributed energy resources (DER), and customer premises or loads. Zones, on the other hand, represent hierarchical levels of power systems management, including process, field, station, operation, enterprise, and market. Notably, the process zone encompasses most of the physical energy conversion devices (Gottschalk, 2017).

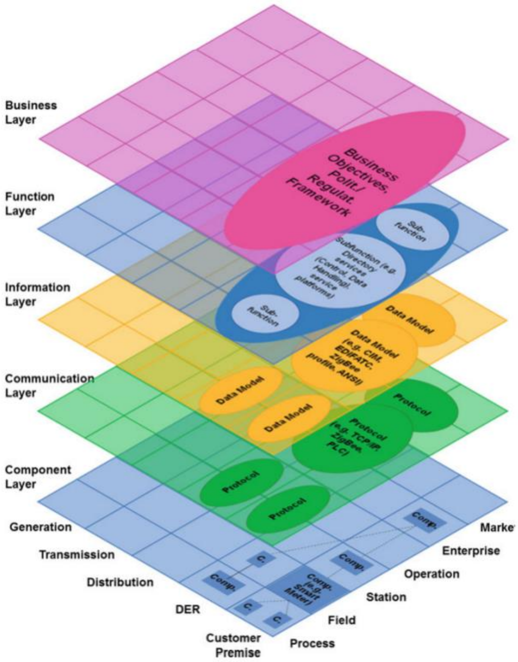

FIGURE 24 THE SMART GRID ARCHITECTURE MODEL (SGAM)

5.1.1.2. GAIA-X Reference Architecture

Adhering to European values and standards, GAIA-X is envisioned as a comprehensive Infrastructure and Data Ecosystem. The GAIA-X architecture leverages digital processes and information technology to foster interconnection across all participants within the European digital economy. By capitalizing on established standards, open-source technologies, and proven concepts, it facilitates open, consistent, high-quality, and user-friendly data exchange and associated services. Furthermore, GAIA-X outlines technical solutions to realize Digital Sovereignty in accordance with EU regulations.

As shown in Figure 25 GAIA-X ARCHITECTURE, GAIA-X is structured into two types of ecosystems[83]:

[83] https://ingenrieth-online.de/fileadmin/rin/files/gaia-x-technical-architecture.pdf

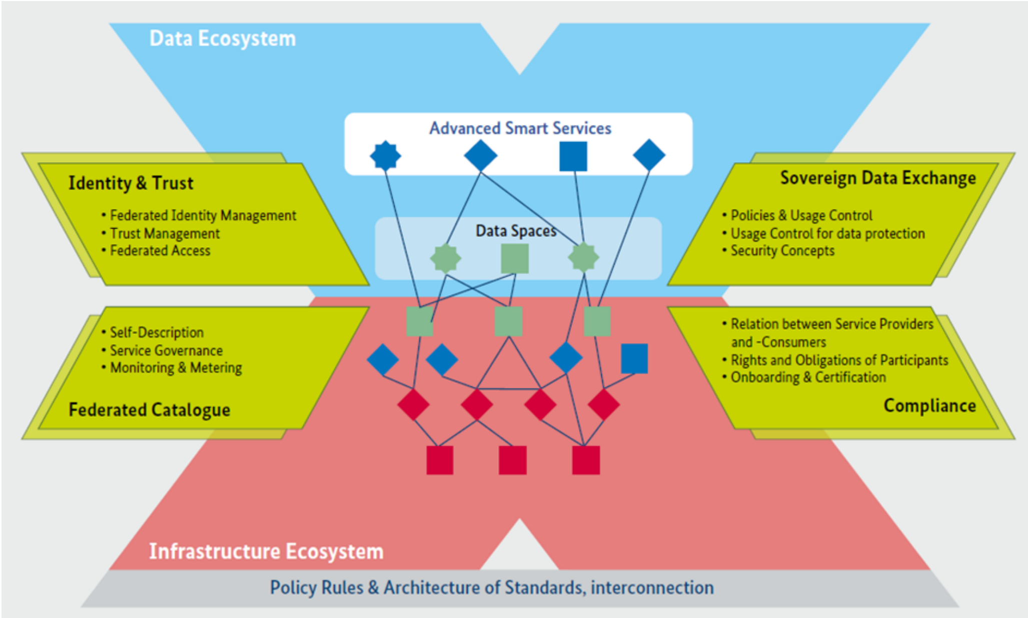

FIGURE 25 GAIA-X ARCHITECTURE

- **GAIA-X Infrastructure Ecosystem** - Services and necessary infrastructure components provided to store, transfer and process data. Stakeholders in the Infrastructure Ecosystem: Cloud Service Providers, High Performance Computing, Sector specific Clouds, Edge Clouds, Interconnection and Network Providers,

- **GAIA-X Data Ecosystem** - Deals with data as the main business asset. Stakeholders in the Data Ecosystem: Data Provider, Data Consumer, Data Owner, Providers of Advanced Smart Services

To bring the architecture principles to life, a set of Federation Services is defined, implemented, and operated. Federation Services are grouped into four domains:

- **Identity and Trust:** To ensure the secure exchange of data, mechanisms are implemented to validate the identities of both data providers and consumers. This process involves the verification of electronic certificates associated with the data connector endpoints. This information is utilized by the connector itself and referenced within the Data Administration and Policy Specification (DAPS) framework.

- **Federated Catalogue (Interoperability):** Data endpoints are integrated through the Federated Catalogue services. This service leverages a Metadata Broker, which relies on "Self-Descriptions" for data characterization. Additionally, a Connector Ontology is employed to furnish unambiguous attribution concerning the semantics and ontological structure of the provided data. This comprehensive approach ensures clear understanding of the data being exchanged.
- **Sovereign Data Exchange:** These services empower each participant within the Infrastructure Ecosystem to exert granular control over data usage during exchange. This eliminates the need for individual agreements and bespoke technological solutions with every counterparty. Sovereign Data Exchange is facilitated by data connectors adhering to pre-defined standards and is further bolstered by the complementary federation services.
- **Compliance:** Compliance of the Connector and the technological standards and agreed polices is provided though certification bodies.

Within the GAIA-X architecture, several core elements are defined as Assets. These Assets encompass Nodes, Services, Service Instances, and Data Assets. A GAIA-X Node represents a computational resource, while a Service signifies a cloud offering. Service Instances, in turn, embody the concrete realization of a

Service deployed on specific Nodes. Finally, Data Assets refer to datasets made accessible to Consumers through a Service that acts as the access point for the data.

GAIA-X prioritizes the establishment of a standardized rule set. This rule set fosters interoperability across data infrastructure elements. Furthermore, it facilitates the anchoring of negotiated data exchange policies throughout the entire technology stack, enabling comprehensive traceability from policy definition to hardware execution.

To guarantee end-to-end adherence to compliance, interoperability, and portability across the entire architecture stack (both horizontally and vertically), an initial methodology is required. This methodology would encompass referencing relevant technical standards (e.g., Identity and Access Management (IAM), Common Data Standards). Additionally, it would involve the compilation of pertinent standards, policies, and open APIs. These elements act as critical facilitators for data sharing, portability, and interoperability within the ecosystem.

To ensure security and data protection within the GAIA-X ecosystem, along with technical solutions, organizational and governance aspects should also be considered. Following techniques are applied in GAIA-X to ensure trust:

- **Federated Identity Management:** In the digital realm, an identity serves as a unique characterization of an individual or asset. Identity Management (IdM) pertains to the process of verifying whether an entity is legitimately who or what it claims to be. IdM encompasses the entire lifecycle of identity information, including creation, modification, and deletion. Complementing IdM is the concept of trust, which establishes the legitimacy of a pre-determined identity. A federated identity, in turn, represents the linkage of a digital identity with attributes that may be dispersed across various identity management systems. This approach enables a more comprehensive and distributed identity framework.
- **Decentralized Identifiers:** GAIA-X's decentralized architecture mitigates the risk of control by a select few, fostering a more inclusive environment for participation by all stakeholders, regardless of size. Furthermore, decentralization imbues the system with key technological advantages such as redundancy, thereby enhancing resilience against outages and potential exploitation.
- **Cryptographical Verification of Self-Descriptions:** GAIA-X leverages Self-Descriptions to characterize both Assets and Participants within the ecosystem. These descriptions detail the properties and claims associated with each Asset or Participant and are linked to their unique identifiers. The onus of creating a Self-Description falls upon the provider of the corresponding Asset. To ensure a robust technical trust framework, cryptographic materials and verification methods are required for secure operations. Currently, there is exploration into utilizing a decentralized public key infrastructure (DPKI) concept in conjunction with decentralized identifiers (DIDs). This approach aligns with the privacy and self-sovereignty requirements of GAIA-X, while establishing a chain of trust that eliminates the need for a centralized, universally traceable unique identifier system.
- **Accreditation and Certification Processes:** GAIA-X doesn't rely on a single, central certification authority. Instead, it leverages a decentralized approach where participants are accredited by authorized bodies against pre-defined compliance criteria. This ensures adherence to GAIA-X standards and fosters trust within the ecosystem.

5.1.1.3. FIWARE Reference Architecture

FIWARE's reference architecture emphasizes open standards to create interoperable smart solutions. It features a central "Context Broker" that acts like a digital city model, integrating data from various sources and making it accessible to different applications for analysis and decision-making (see Figure 26 FIWARE Iot agent based architecture). This promotes data sharing and avoids building isolated systems.

- **Communication protocol:** The Next Generation Service Interfaces (NGSI) API provides a straightforward and powerful method for accessing data sources within a data space using a RESTful interface. Over time, the NGSI API specifications have been iteratively improved based on developer feedback and implementation experiences. The NGSIv2 API represents a mature iteration of the API, finding widespread adoption in production systems across diverse industries. The evolution continues under the ETSI Context Information Management Industry Specification Group (CIM ISG). The latest version, NGSI-LD API, was initially published by ETSI in 2019 and remains under development, with the most recent iteration being version 1.7. Primarily used for data integration, the NGSI-LD API is implemented by the Context Broker, the core component of any "powered by FIWARE" architecture (further detailed in the software components section).
- **Semantic models**: Realizing comprehensive interoperability with data exchange APIs necessitates the utilization of common data models that seamlessly integrate with the API format. The Smart Data Models initiative addresses this requirement by offering a comprehensive collection of data model specifications. These specifications are meticulously mapped to compatible JSON and JSON-LD data structures, ensuring alignment with the NGSI-LD API. This approach fosters data interoperability within i4Trust data spaces. Furthermore, the initiative extends its reach by providing additional export formats such as CSV, SQL, DTDL, and GeoJSON features, catering to a broader range of use cases.
- **Software components:** FIWARE is a curated open-source platform comprised of interoperable components that can be readily assembled. This modular approach, alongside compatibility with third-party components, fosters the rapid development of Smart Solutions. FIWARE offers a rich suite of components and services specifically designed to facilitate the creation of robust and effective data spaces. The cornerstone of any "Powered by FIWARE" platform or solution is the FIWARE Context Broker Generic Enabler. This critical component serves as the foundation for context information management in smart solutions. It centralizes context data originating from various providers and makes it readily accessible to numerous consumers.
- **Context broker:** The FIWARE Context Broker serves as the architectural linchpin. This component fulfills a critical function in smart solutions: context information management. It facilitates efficient updates, retrieval, and access to context data in highly decentralized and large-scale environments. In essence, a context broker maintains a digital twin representation of real-world entities (both logical and physical) and concepts relevant to the specific problem being addressed. Examples of such entities within an industrial setting might include AGV robots, palletizer robots, warehouse storage shelves, automatic doors, shop floor operators, products in storage, and CRM system orders. The FIWARE Community fosters innovation by providing open-source implementations of the Context Broker, such as Orion-LD, Scorpio, and Stellio.
- **Security Management:** Security management involves several components. From those providing identification, policy enforcement points and policy decision points among others. **Keyrock** emerges as a freely available Identity and Access Management (IAM) solution. It empowers organizations to secure their applications and services through a centralized authentication and authorization portal. Keyrock offers a comprehensive feature set, including user management, integration with social login providers, and multi-factor authentication for enhanced security. Furthermore, Keyrock seamlessly integrates with existing identity providers like LDAP and Active Directory. Developed in Java, Keyrock is open-source software distributed under the Apache License 2.0. This licensing model facilitates adoption and customization within various organizational settings. Within the FIWARE ecosystem, **Wilma** stands out as the preferred Policy Decision Point (PDP) implementation. This prominence is attributed to its effortless integration capabilities with other FIWARE components. Wilma is specifically designed for seamless

operation with OAuth2 and XACML protocols, the cornerstones of authentication and authorization within FIWARE. Furthermore, each Generic Enabler (GE) incorporates Wilma as an overlay on their REST APIs. This widespread adoption has resulted in extensive testing and validation of Wilma across a multitude of use cases. FIWARE offers a dedicated Generic Enabler (GE) named **Authzforce**, specifically designed to provide a reference implementation for the Authorization PDP (Policy Decision Point). As mandated by the GE specification, Authzforce features a well-defined API that facilitates the retrieval of authorization decisions based on authorization policies and requests received from PEPs (Policy Enforcement Points). The API adheres to the REST architectural style and leverages the XACML v3.0 standard for both authorization policy format and evaluation logic, as well as request/response formatting for authorization decisions. For clarity, the XACML standard employs the terms PDP and PEP to denote Policy Decision Point and Policy Enforcement Point, respectively. While Authzforce functions as a PDP within this reference implementation, it's important to note that XACML architecture often necessitates the inclusion of a separate PEP component to safeguard your application.

- **Persistent components:** Persistence components are software elements responsible for long-term information storage and retrieval for historical data analysis. These components collect data from other sources, often by subscribing to updates from the Context Broker. One such persistence component is **Cygnus-LD**, a Generic Enabler that facilitates the preservation of historical context data. Cygnus-LD achieves this by generating data streams that can be directed towards various data sinks, including popular databases like PostgreSQL and ArcGIS, or public Open Data Platforms like CKAN. It leverages Apache Flume as its core technology. It's important to note that Cygnus-LD's functionality may be redundant when using Orion-LD, as context brokers like Scorpio already offer built-in persistence capabilities.
- **IoT agents:** The IoT agents gather information from specific IoT sensors and transfer them into the main components of the platform: IoT Agent for JSON - a bridge between HTTP/MQTT messaging (with a JSON payload) and NGSI/NGSI-LD, IoT Agent for LWM2M a bridge between the Lightweight M2M protocol and NGSI/NGSI-LD, IoT Agent for Ultralight - a bridge between HTTP/MQTT messaging (with an UltraLight2.0 payload) and NGSI/NGSI-LD, IoT Agent for LoRaWAN - a bridge between the LoRaWAN protocol and NGSI/NGSI-LD, IoT Agent for Sigfox - a bridge between the Sigfox protocol and NGSI/NGSI-LD, IoT Agent Library - library for developing your own IoT Agent, almost all the IoT Agents are using this library to develop their concrete bridge between legacy systems and NGSI/NGSI-LD.

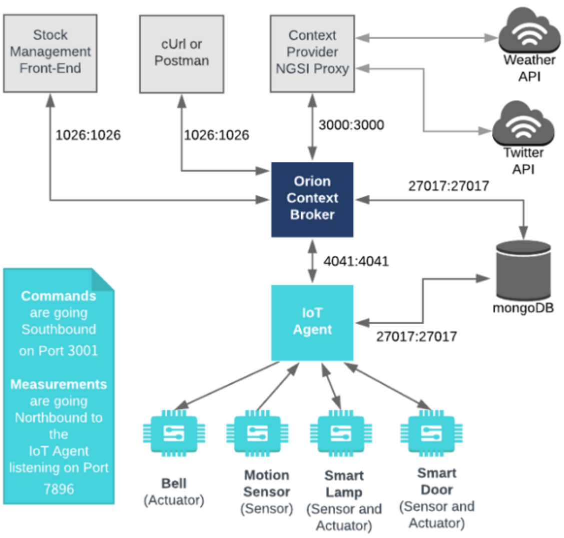

FIGURE 26 FIWARE IOT AGENT BASED ARCHITECTURE

5.1.1.4. Alliance for Internet of Things Innovation: Integration of IoT and Edge Computing in Data Spaces

The Alliance for Internet of Things Innovation (AIOTI) provides three important architecture perspectives: computing continuum, federation, and marketplace. A computing continuum perspective integrating IoT and edge computing is needed[84]. Figure 27 Computing continuum perspective of data spacesshows Data Spaces where this continuum is visualised from left to right.

- IoT devices carry out some data operations and exchange data,
- Edge systems carry out further data operations and exchange further data,
- Cloud systems carry out further data operations and exchange further data

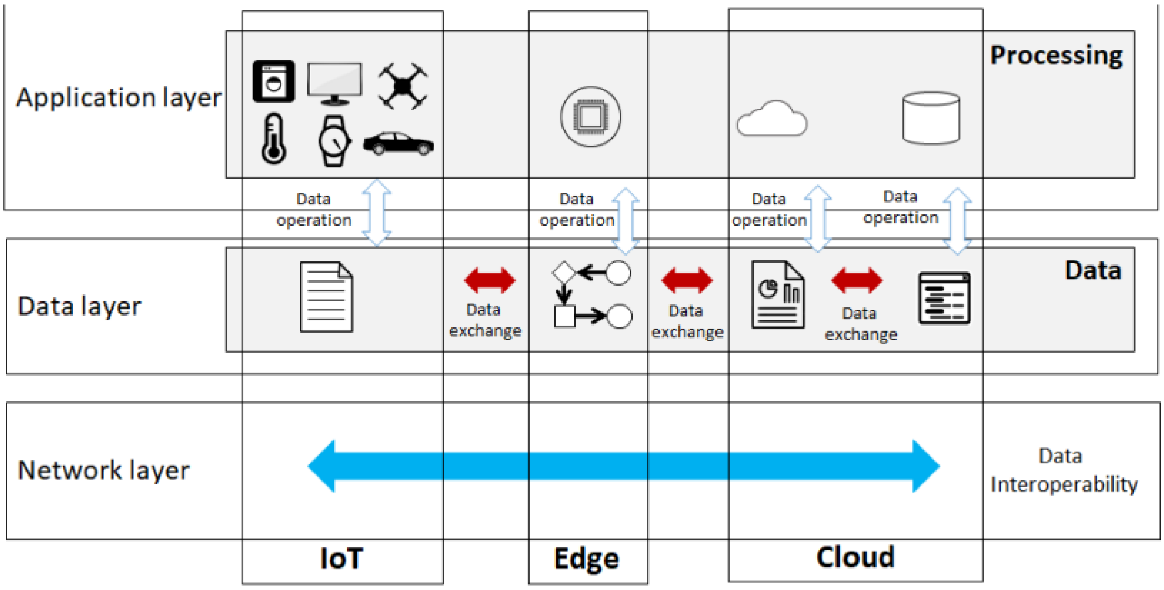

FIGURE 27 COMPUTING CONTINUUM PERSPECTIVE OF DATA SPACES

The federated system perspective can also be needed. Figure 28 Federated systems perspective of data spaces shows this: while data exchange can take place within a data space ecosystem, two separate ecosystems can also exchange data. Federation is suitable to achieve cross domain exchange e.g. between the energy and the transport domain.

[84] https://internationaldataspaces.org/wp-content/uploads/AIOTI-Guidance-for-IoT-Integration-in-Data-Spaces-Final.pdf

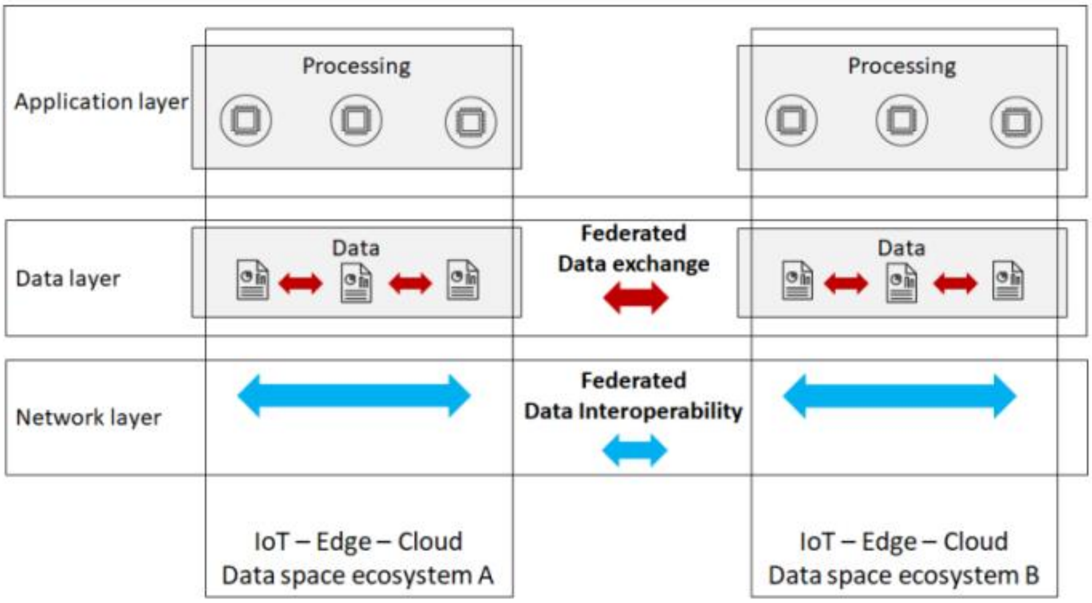

FIGURE 28 FEDERATED SYSTEMS PERSPECTIVE OF DATA SPACES

A data marketplace perspective can also be needed. Figure 29 DATA COLLECTION SYSTEM AND DATA MARKETPLACE PERSPECTIVEshows a data collecting system, a data trading system, consisting of a market place, data providers and data consumers.

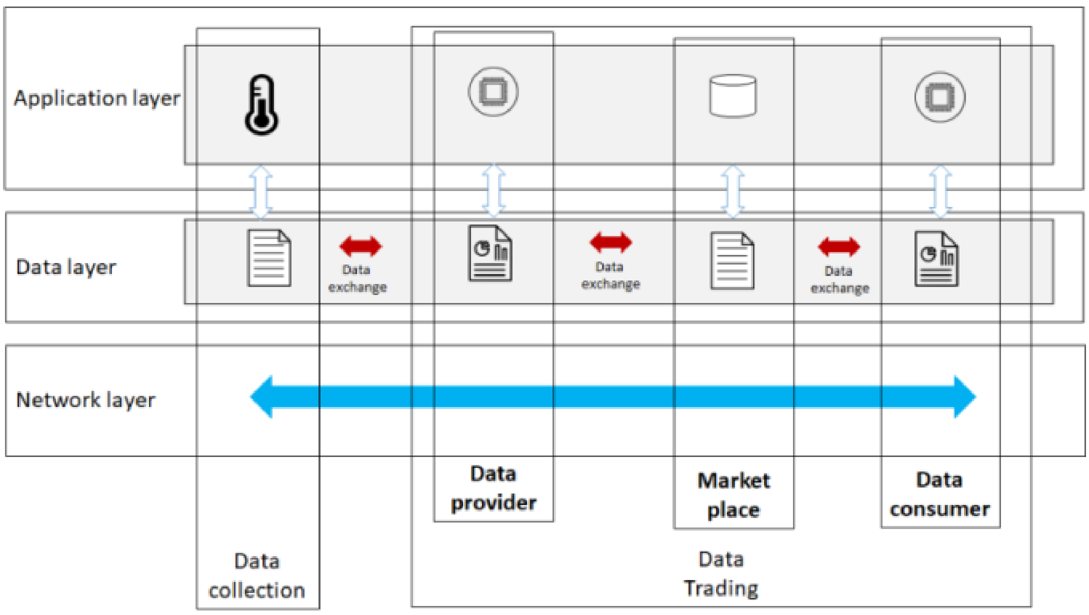

FIGURE 29 DATA COLLECTION SYSTEM AND DATA MARKETPLACE PERSPECTIVE

5.1.1.5. International Data Space Association (IDSA) Reference Architecture

The concept of data sovereignty is paramount within the International Data Spaces (IDS) framework. It signifies an entity's (individual or organization) complete autonomy over its data. The IDS initiative addresses this critical aspect through a Reference Architecture Model (RAM) that encompasses not only data sovereignty but also related considerations such as secure and trusted data exchange within business ecosystems.

Aligned with established system architecture models and standards (e.g., ISO 42010, 4+1 view model), the RAM leverages a five-layer structure[85]. This structure effectively captures the diverse concerns and perspectives of various stakeholders, with varying levels of detail provided at each layer. A visual representation of the general structure can be found in Figure 30 IDSA Reference architecture model LAYERS AND PERSPECTIVES. It's important to note that the RAM incorporates three additional perspectives (Security, Governance, Certification) that apply horizontally across all five layers.

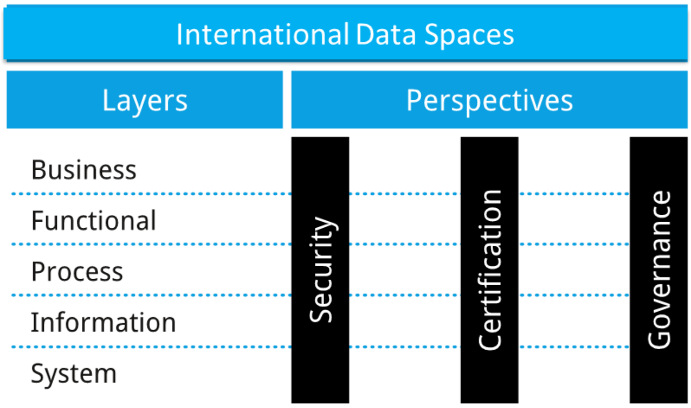

FIGURE 30 IDSA REFERENCE ARCHITECTURE MODEL LAYERS AND PERSPECTIVES

Based on this Reference Architecture Model a Certification Scheme is derived that validates the compliance of participants and components to this Reference Architecture Model (IDS Knowledge Base, 2024). Such components can be provided as Free and Open-Source Software or proprietary software. The operation of a data space instance is described in the IDSA Rulebook based on the BLOFT (Business, Legal, Operational, Functional, Technical) aspects of a data space (Figure 31 IDSA FRAMEWORK).

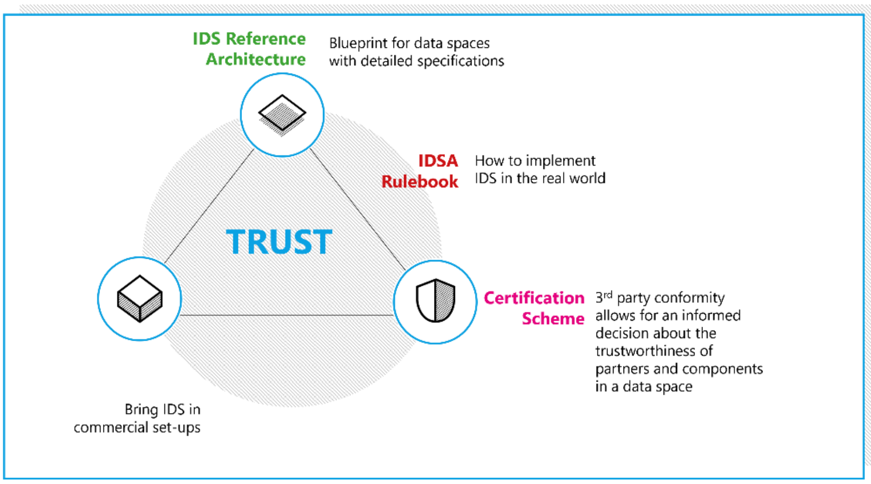

FIGURE 31 IDSA FRAMEWORK

Roles and interactions in the International Data Spaces

[85] https://docs.internationaldataspaces.org/ids-knowledgebase

The IDS Reference Architecture Model (IDS-RAM) provides several elements, roles and interactions that constitute an infrastructure for sovereign data exchange (Figure 32 IDS Roles and Interactions). There are four categories of roles (8):

- Category 1: Core Participant
- Category 2: Intermediary
- Category 3: Software / Service Provider
- Category 4: Governance Body

The Core Participants are **Data Owner**, **Data Provider**, **Data Consumer** and **Data Use**r. They are involved and required every time data is exchanged in the IDS. **Intermediaries** act as trusted entities. These are the **Broker Service provider**, an intermediary that stores and manages information about the data sources available in the IDS; the **Clearing House**, that provides clearing and settlement services for all financial and data exchange transactions; and the **Identity Provider**, which consists of a Certification Authority (managing digital certificates for the participants of the IDS), a **Dynamic Attribute Provisioning Service** (DAPS, managing the dynamic attributes of the participants), and a service named **Dynamic Trust Monitoring** (DTM, for continuous monitoring of the security and behavior of the network. The **Vocabulary provider** technically manages and offers vocabularies (i.e. ontologies, reference data models, or metadata elements). The 3rd category comprises IT companies providing **software and/or services** (e.g., based on a software-as-a-service model) to the participants of the IDS. The **Certification Body**, **Evaluation Facilities**, and the **International Data Spaces Association** are the **Governance Bodies** of the International Data Spaces.

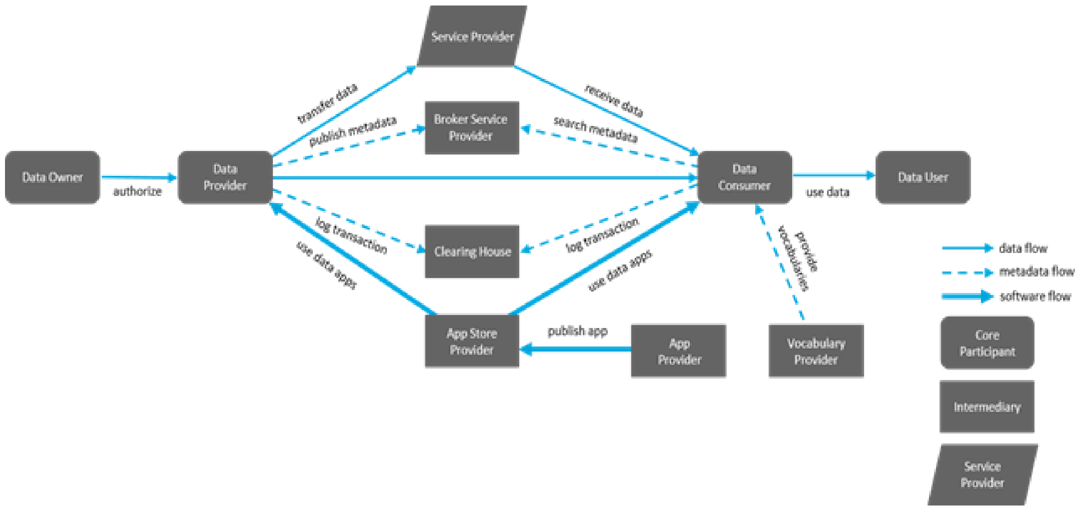

FIGURE 32 IDS ROLES AND INTERACTIONS

Within the International Data Spaces Reference Architecture Model (RAM), the IDS Connector emerges as the central component. Functioning as the access point to this trusted ecosystem, the Connector assumes primary responsibility for data exchange. Leveraging a peer-to-peer network concept, data within an IDS ecosystem is transferred directly between the Connectors of the Data Provider and the Data Consumer.

IDS Reference testbed

The IDS Reference Testbed is a piece of open-source software that consists of basic IDS components complying to the IDS specifications for establishing connections and communication. These components are the Certificate Authority (CA), the Dynamic Attribute Provisioning Service (DAPS), a Meta Data Broker and two Dataspace Connectors (Figure 33 IDS Reference Testbed).

Moreover, an automated test suite is included for testing a data connector on criteria for interoperability and compliance to the IDS specifications. For testing on those certification criteria, a questionnaire tool is available that guides through those aspects.

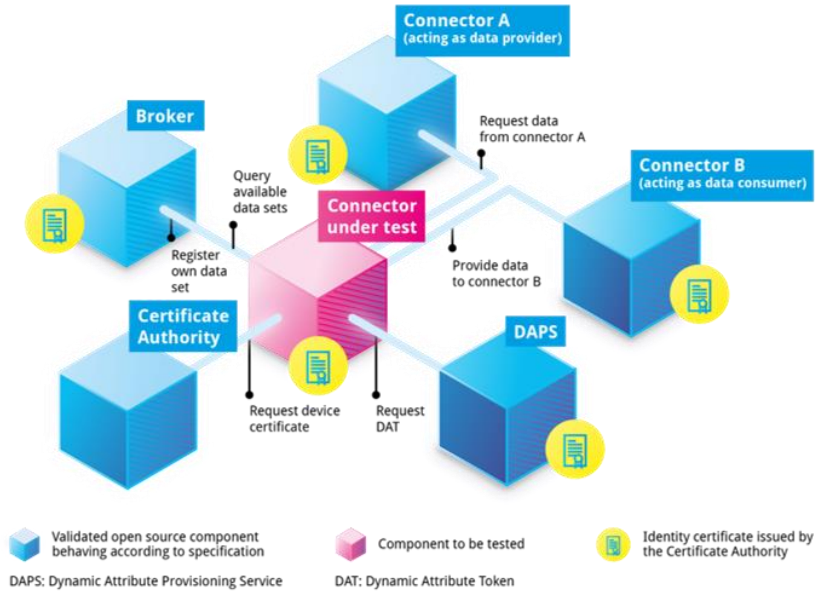

FIGURE 33 IDS REFERENCE TESTBED

Minimum Viable Data Space

A Minimum Viable Data Space (MVDS) is a combination of components that enable the creation of a data space with just enough features to be usable for secure and sovereign data exchange, as specified by the International Data Spaces Association (IDSA) (Figure 34 Minimum Viable Data Space). The goal of an MVDS is to streamline the implementation process, making it easier and faster for experimenters to create a working data space with secure and sovereign data exchange. By starting with an MVDS, the development team can iterate quickly and respond to the requirements of the data space, adjusting as necessary to meet the needs of users. The MVDS is the unique solution provided by IDSA Head Office, as current best practice.

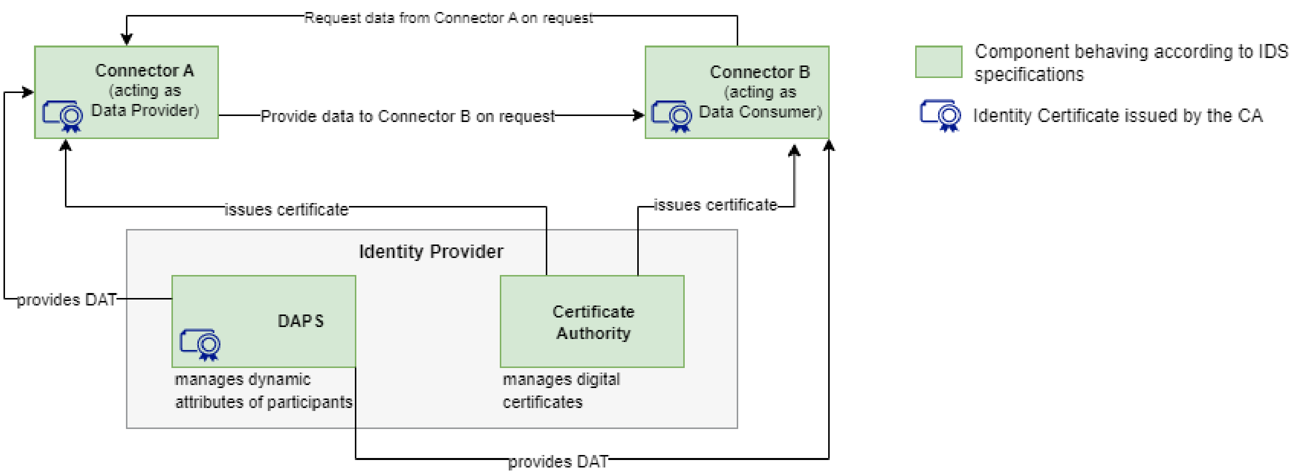

FIGURE 34 MINIMUM VIABLE DATA SPACE

5.1.1.6. Data Spaces Support Centre

The **Data Spaces Support Centre (DSSC)** is a European Union-funded initiative that facilitates common data spaces in different sectors to create an interoperable data sharing environment. The DSSC explores the needs of the data spaces initiatives, including common requirements and best practices, and delivers the Data Spaces Blueprint, composed of common building blocks in business, legal, operational, technical, and societal aspects5. The initiative is aimed at initiatives and companies that want to create sovereign Data Spaces.

The DSSC wants to enable data spaces to reach a higher maturity level faster, enabling them to focus on their business or societal objectives. In addition, it wants to ensure future benefits from synergies and foster data space interoperability, making it easier to connect to multiple data spaces and enabling economies of scale for data space intermediaries.

Therefore, it is important to converge and identify a set of common standards for each building block and guidelines on how they can be used together. Business and technological innovation can change things in the future, but currently, it is unlikely that there is a 'one size fits all' solution for data spaces. It remains important to identify options and common standards for these building blocks.

Building blocks come in two categories:

- **Business and Organisational building blocks**: These relate to business models of data spaces that provide insights into how their value is created. They relate to the governance of data spaces, which gives insights into, for instance, the organizational form and how the participants are managed. They also relate to the legal frameworks the data spaces must comply with.

  The organizational and business building blocks look at the business, governance and legal topics and decisions primarily from the perspective of the data space and focus on the data space level. But clearly, we must keep all the different levels in the discussion. Each of the eight organizational and business building blocks enables a unique capability not covered by any other building block, see Figure 35 Overview of Business & Organizational Building Blocks / DSSC blueprint[86].

FIGURE 35 OVERVIEW OF BUSINESS & ORGANIZATIONAL BUILDING BLOCKS / DSSC BLUEPRINT

- **Technical building blocks**: These relate to the technical aspects of a Data Space and the technical agreements that individual participants and trusted data space intermediaries need to adhere to. The technical specifications outline the use of specific technology solutions and processes that are necessary for ensuring the desired functionality of a given building block.

[86] https://dssc.eu/space/BPE/179175433/Data+Spaces+Blueprint+%7C+Version+0.5+%7C+September+2023

Technical capabilities are structured according to three pillars (see Figure 36 technical building blocks / Blueprint of DSSC):

- **Data interoperability:** capabilities needed for data exchange are semantic models, data formats and interfaces (APIs). This also includes functionalities for provenance & traceability.
- **Data sovereignty and trust:** capabilities needed for the identification of participants and assets in a data space, the establishment of trust and the possibility to define and enforce policies for access & usage control.
- **Data value creation:** capabilities used to enable value-creation in a Data Space, e.g. by registering and discovering data offerings or services and to provide value-added services.

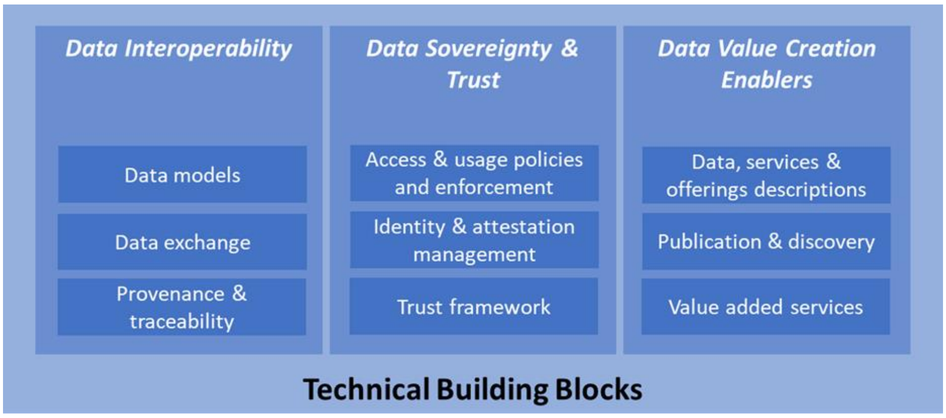

FIGURE 36 TECHNICAL BUILDING BLOCKS / BLUEPRINT OF DSSC

5.1.2. Review of European Research Projects on Reference Architecture Models

5.1.2.1. OPEN DEI Horizon 2020 project: Aligning Reference Architectures, Open Platforms and Large-Scale Pilots in Digitising European Industry

OPEN DEI was a Horizon 2020 project that aimed to provide the necessary measures, channels and mechanisms to ensure cooperation between pilot projects in different domains – manufacturing, agriculture, energy, healthcare - so that synergies can be exploited, knowledge can be shared, and impact is maximized.

The OPEN DEI Reference Architecture Framework (RAF) is grounded in six key principles: interoperability, enabling seamless communication across systems; openness, promoting the use of standard specifications for broad accessibility; reusability, encouraging the development of modular components for flexible deployment; avoidance of vendor lock-in, ensuring a diverse technology landscape; security and privacy, prioritizing robust protection of information; and support for a data economy, facilitating secure and efficient data exchange to drive economic growth and innovation.

The OPEN DEI Reference Architecture Framework (RAF) functions as a high-level blueprint for platforms that can support digital transformation across organizations. However, it is important to distinguish the RAF from a specific business case or prescribed technological approach. The project focuses on providing recommendations for achieving convergence across diverse criteria and viewpoints, rather than delivering software or outlining a singular business model.

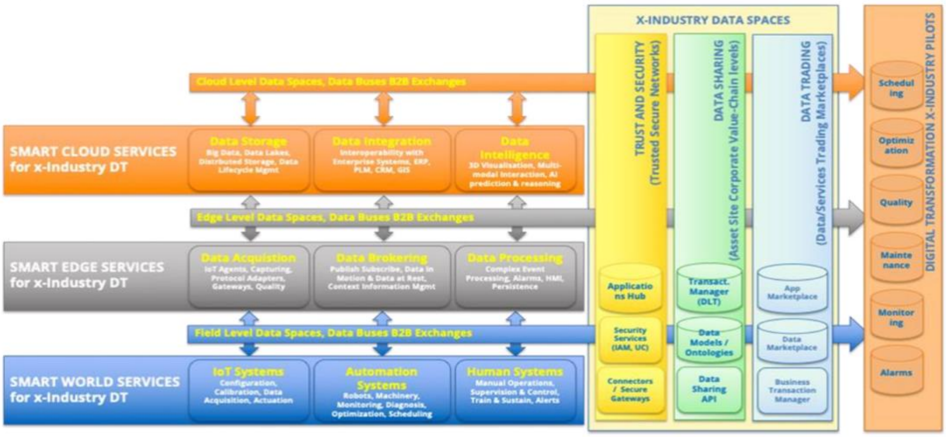

FIGURE 37 OPEN DEI

Figure 37 OPEN DEI illustrates how horizontal, cross-industry data transformations feed the cross-industry data space. These transformations provide essential capabilities like trust and security, data sharing, and data trading, enabling the realization of both sector-specific and cross-sector digital transformation pilots.

The OPEN DEI Reference Architecture Framework (RAF) aspires to be a universal mapping tool for various reference architectures and digital platforms. This is achievable due to its high level of abstraction. The RAF offers conceptual guidance without dictating specific implementations.[87]

For a more comprehensive analysis of existing architecture types and interoperability levels, please refer to the relevant project deliverable. The analysis also included the relevant context of Digital Twins. A key takeaway was the critical importance of integration at the API access level, data models, and their associated semantics. While numerous standards documents were referenced, most are inaccessible due to paywalls or controlled access restrictions [88].

A key recommendation arising from the analysis is the adoption of ISO-23903 as a cross-domain reference framework. This standard's strength lies in its ability to provide an abstract and generic model suitable for various system types. Furthermore, ISO-23903 facilitates the representation of systems-of-systems through a theoretical approach that emphasizes the importance of architectural design, ontologies, and policy considerations during the modeling process. The framework enables the flexible composition and decomposition of system domains based on granularity levels, allowing for the effective description of their development evolution.

Complementing the adoption of ISO-23903, a second key recommendation is to adhere to the OPEN DEI design principles for Data spaces. These principles encompass four critical categories: infrastructure, trust, data value, and governance (Figure 38 Data Space Materialization of OpenDEI. Notably, the OPEN DEI principles represent a synthesis of the building blocks established by FIWARE and ISHARE initiatives[89].

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[87] https://www.opendei.eu/open-dei-reference-architecture-for-cross-domain-digital-transformation/.

[88] Kung , Antonio, et al. Reference Architectures and Interoperability in Digital Platforms. *OPENDEI*. [Online] 09 2022. https://www.opendei.eu/wp-content/uploads/2022/10/REFERENCE-ARCHITECTURES-AND-INTEROPERABILITY-IN-DIGITAL-PLATFORMS.pdf.

[89] Dognini , Alberto, et al. Data Spaces for Energy, Home and Mobility. *OPENDEI*. [Online] October 2022. https://www.opendei.eu/wp-content/uploads/2022/10/OPEN-DEI-Energy-Data-Spaces-EHM-v1.07.pdf. 10.5281/zenodo.7193318.

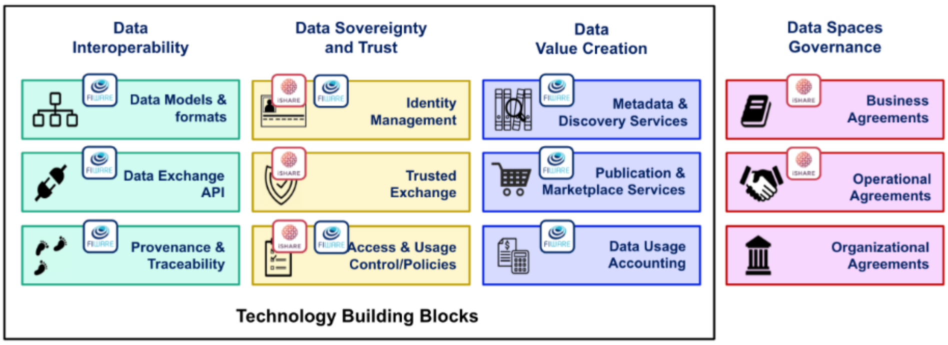

FIGURE 38 DATA SPACE MATERIALIZATION OF OPENDEI

For the Energy Domain specifically, the well-established and widely adopted CIM (Common Information Model) standards are recommended as a foundation. This choice leverages the existing acceptance of CIM standards among Transmission System Operators (TSOs) and Distribution System Operators (DSOs). However, to fully realize an interoperable European data space, it is crucial to focus on two key areas: increasing participant numbers and enhancing data quality across the continent. Achieving this vision necessitates addressing the issue at a regulatory and legislative level.

A suggestion for a Reference Architecture for Energy using Digital Twins is presented in Figure 39 RA for Energy using Digital Twins.

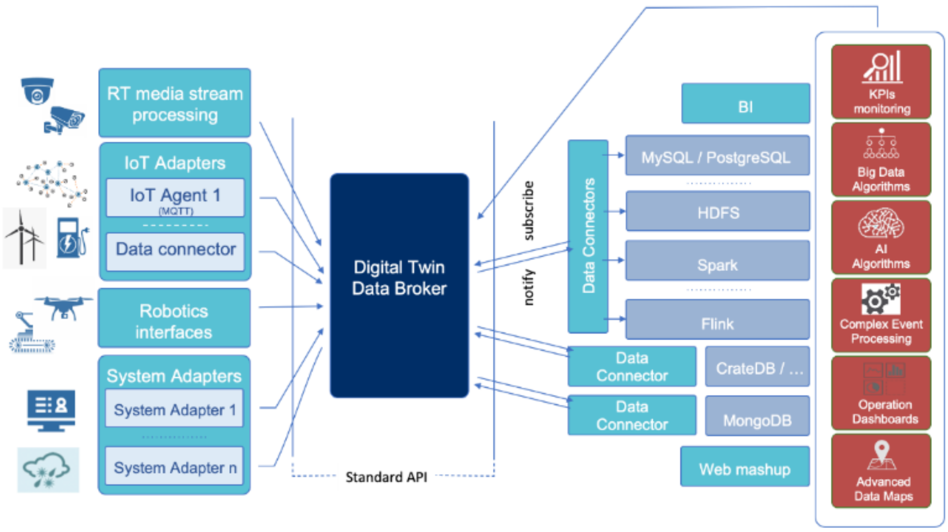

FIGURE 39 RA FOR ENERGY USING DIGITAL TWINS

5.1.2.2. Interconnect Horizon 2020 project: Interoperable solutions connecting smart homes, buildings and grids

The H2020 Interconnect project tackles a critical challenge: achieving semantic interoperability. This refers to the ability of digital systems to seamlessly exchange data with a clear, shared, and agreed-upon meaning. Semantic interoperability is a cornerstone for realizing the vision of a Digital Single Market. The project leverages ontologies, such as SAREF, and knowledge exchange mechanisms to bridge this gap. This approach empowers diverse providers and companies to offer competitive and cost-effective solutions while simultaneously preventing vendor lock-in and closed, vertical technology implementations. The project's core innovation lies in its large-scale deployment of semantic interoperability concepts, aiming for a high level of maturity and broad applicability.

To realize the ambitious goal of large-scale semantic interoperability deployment, the InterConnect project undertook a meticulous analysis of existing IoT reference architectures. This analysis, with a particular focus on the Smart Grid Architecture Model (SGAM) for interactions within the Smart Energy domain, informed the development of the project's core reference architecture: the Secure Interoperable IoT Smart Home/Building and Smart Energy system Reference Architecture (SHBERA). SHBERA facilitates the implementation of digital services across diverse deployments, encompassing devices, systems, and cloud-based infrastructures. This innovative architecture bridges the gap between the project's two key domains: IoT and Energy, by establishing a common ground for seamless interaction.

The SHBERA reference architecture aims to establish a unified perspective on system design. This perspective clarifies the relationships between various components in a way that is not only easy to understand but also affordable and fosters trust. SHBERA serves as a foundation for seamlessly interconnecting services and devices within the Smart Grid, connected Smart Homes and Buildings, enabling bidirectional communication and data exchange.

The SHBERA reference architecture incorporates several key domains:

User Domain: This multifaceted domain encompasses the various user roles encountered in the project's use cases. It highlights the diversity of user types while emphasizing the potential for architectural combinations.

Control, Comfort & Convenience (CCC) Services Domain: This domain focuses on the actors involved in providing and benefiting from CCC services, as well as any non-energy services that contribute to or enable the pilot project.

Energy Services Domain: This domain centers around the key actors delivering energy services and the services themselves, which are essential for the pilot use cases.

Semantic Interoperability Layer Domain: This domain comprises configured instances of interoperability adapters and smart connectors. These reside on digital platforms provided by project partners and are supported by services introduced within the semantic interoperability framework.

Home/Building Domain: This domain groups the hardware and software components deployed within residential or commercial buildings, including appliances, IoT devices, sensors, and more.

Energy System Domain: This domain encompasses key actors from the energy sector, along with resources and services provided by Transmission System Operators (TSOs) and Distribution System Operators (DSOs).

The SHBERA reference architecture can be further examined through several focused viewpoints, as illustrated in Figure 40 INTERCONNECT'S SHBERA AND THE DIFFERENT ARCHITECTURAL VIEWPOINTS:

Smart Energy Reference Architecture (SERA): This viewpoint offers a detailed perspective on the energy system, focusing on its components and interactions.

Smart Home/Building IoT Reference Architecture (SHBIRA): This viewpoint delves into the inner workings of smart homes and buildings, examining the interplay between IoT devices and related components.

Interoperability Framework Architecture (IFA): This viewpoint sheds light on the technical framework that facilitates communication and data exchange between different systems.

Semantic Interoperability Layer (SIL): This viewpoint explores the layer responsible for ensuring clear and consistent data exchange through the use of shared meanings, ontologies[90].

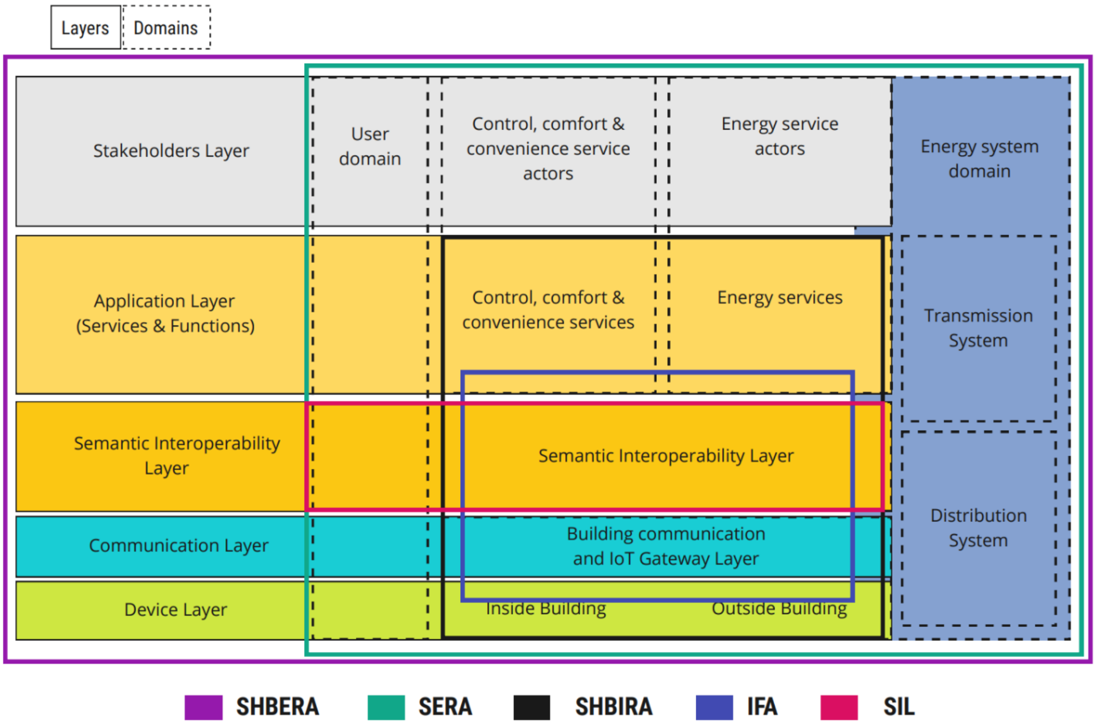

FIGURE 40 INTERCONNECT'S SHBERA AND THE DIFFERENT ARCHITECTURAL VIEWPOINTS

5.1.2.3. PlatONE Horizon 2020 project: PLATform for Operation of distribution NEtworks

The shift to renewable energy sources brings new challenges for managing electricity grids. Unpredictable wind and solar power, combined with fluctuating consumer demand, make it harder for operators to keep the grid stable. Traditionally, these issues have been tackled with separate solutions. However, the PlatONE project proposed a new way to manage both problems together using a unified data platform.

With this objective in mind, the Platone Open Framework endeavors to establish a fully replicable and scalable system. This system will facilitate distribution grid flexibility and congestion management through the implementation of Peer-to-Peer (P2P) market models. These models encompass all potential actors across various levels, including Distribution System Operators (DSOs), Transmission System Operators (TSOs), customers, and aggregators.

The development of the PlatONE Framework is based on an iterative approach, using feedback coming from the demo pilot sites and a laboratory test to find a validated design and implementation approach.

Figure 41 PlatONE Framework Applied to the Italian Demo illustrates the internal structure of the Platone Open Framework by depicting its various components as distinct blocks. These blocks represent the Blockchain Service Layer, Blockchain Access Layer, and the Platone DSO Technical Platform. Additionally, the figure visually represents the interaction between the framework and its stakeholders, along with the diverse systems these stakeholders utilize to exchange information and interact with the platform.[91]

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[90] InterConnect Public / Ontology · GitLab (inesctec.pt)

[91] https://www.platone-h2020.eu/data/deliverables/864300_M38_D3.4.pdf.

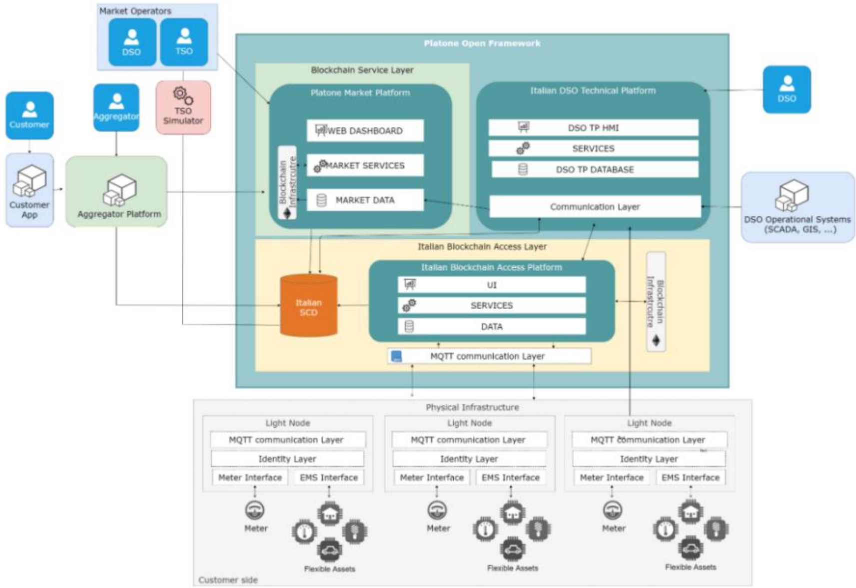

FIGURE 41 PLATONE FRAMEWORK APPLIED TO THE ITALIAN DEMO

The successful operation of Local Flexibility Markets is facilitated by five key platforms:

Market Platform: This core component leverages blockchain technology to store flexibility needs and requests. It matches offers submitted by aggregators to the grid's requirements based on pre-defined rules and agreements established with System Operators.

Aggregator Platform: This platform plays a crucial role in managing flexible resources. It optimizes market strategies and the formulation of flexibility offers.

Blockchain Access Layer: The Blockchain Access Layer serves as the foundation for platform security and trustworthiness. It verifies data originating from Light Nodes and executes Smart Contracts.

Shared Customer Database: This database compiles information accessible via authorized access to all stakeholders engaged in the Local Flexibility Market.

DSO Technical Platform: The DSO Technical Platform executes core tasks according to market timeframes. These tasks encompass power flow analysis, flexibility requests, technical validation of market outcomes, and broadcasting setpoints to flexible resources.

PlatONE aligns with the long-term sustainability goals of the LFE SOGNO project, ensuring compatibility with upstream initiatives focused on open-source platforms for grid operators.

5.1.2.4. INTERRFACE Horizon 2020 project: TSO-DSO-Consumer INTERFACE aRchitecture to provide innovative grid services for an efficient power system

The growing integration of renewables, expanding European grid connections, and local energy initiatives are driving a complex energy landscape. New regulatory requirements for closer collaboration between Transmission System Operators (TSOs) and Distribution System Operators (DSOs) further emphasize this need.

In recognition of this challenge, the European Commission has proposed legislative changes to encourage cooperation among network operators, particularly in procuring balancing and ancillary services, as well as managing congestion. This highlights the importance of projects like INTERRFACE, which address this critical need by facilitating greater coordination between TSOs and DSOs.

The INTERRFACE project's solution lies in the IEGSA platform. This unified platform connects various energy market players, including Market Operators, TSOs, DSOs, Flexibility Service Providers, and Settlement Responsible Parties. IEGSA enables coordinated procurement of essential grid services (balancing, congestion management, and ancillary services) from resources connected to both transmission and distribution grids. It achieves this by implementing multiple coordination schemes between TSOs and DSOs.

The increasing participation of diverse energy stakeholders, both as providers and consumers of flexibility, necessitates a secure platform for information and data exchange. IEGSA effectively addresses this need with its modular architecture, facilitating data exchange with existing European hubs. This design enables interconnection between various actors within the system, including TSOs, DSOs, market participants, and customers.

Beyond just interconnection, IEGSA promotes the digitalization of the energy value chain while ensuring data security and privacy by design. The platform actively seeks to engage various Balancing Service Providers and facilitates access to diverse market platforms with different timeframes. This approach strengthens coordination between TSOs and DSOs by introducing standardized services and market designs.

As a comprehensive suite of tools and technologies, IEGSA integrates multiple actors and systems to address various business requirements. However, its core focus remains facilitating coordinated flexibility procurement between TSOs and DSOs. A detailed illustration of the platform's technical composition can be found in Figure 42 IEGSA Logical Architecture.

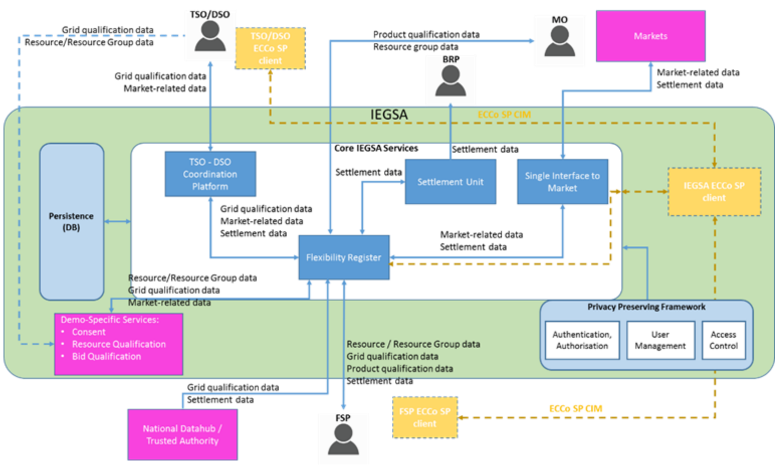

FIGURE 42 IEGSA LOGICAL ARCHITECTURE

The design of IEGSA adheres to the Smart Grid Architecture Model (SGAM) Framework (illustrated in Figure 43). This framework provides a structured approach, and IEGSA's implementation reflects this structure across distinct layers: business, function, information, communication, and components[92].

[92] Renewables Grid Initiative (renewables-grid.eu)

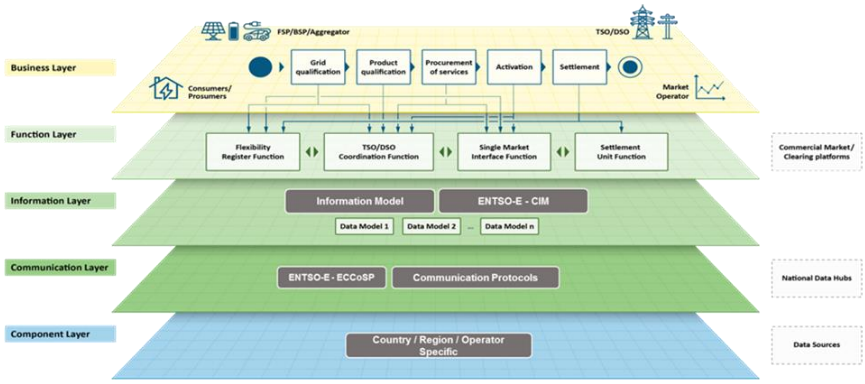

FIGURE 43 SGAM-BASED IEGSA ARCHITECTURAL REPRESENTATION

From a technical perspective, the combined communication, information, and function layers serve as middleware. This middleware bridges the gap between the Business Layer, which captures user needs and their Business Units' Control Systems (BUCS), and the Component Layer, where the specific implementation details for the demonstration project meet the requirements set forth by the Business Layer.

The IEGSA architecture leverages a modular approach, employing four main functional blocks to integrate complementary services and functionalities within the overall framework. Those functional modules - illustrated with blue boxes in Figure 43 are the following:

- At the heart of IEGSA lies the **Flexibility Register (FR)** module. This core component handles various processes, including user management, resource and resource group registration, interaction with the consent manager, product definition, product triggering, and grid and bid qualification. All IEGSA users, including Flexibility Service Providers (FSPs), Market Operators (MOs), and System Operators (SOs), can access the FR module, but with varying permission levels. To facilitate resource management, the FR module offers a user interface (UI) with functionalities for viewing, updating, and adding individual resources and resource groups. Additionally, the UI provides a qualification status tab for monitoring the qualification process of resources and resource groups, along with functionalities for defining products and submitting product qualification requests.
- The **TSO-DSO Coordination platform** serves as the core module for facilitating collaboration between System Operators (SOs). This module interacts with the Flexibility Register to access functionalities related to bid and grid qualification services, as well as market processes such as merit-order list documents. To support SO activity, the platform offers a dedicated user interface (UI) for viewing resources and resource groups. Notably, SOs have the authority to modify resource qualification statuses within this interface. Furthermore, the platform provides SOs with a comprehensive dashboard displaying merit order lists from all integrated IEGSA markets. This dashboard may also empower SOs to directly activate specific bids within IEGSA. Activated bids can then be viewed within the platform's "Trades" environment.
- The **Single Interface to Market (SITM)** functions as a critical backend component, acting as the gateway for connecting IEGSA to various energy markets. This essentially facilitates the exchange of market-related data. The SITM adopts a set of standardized RESTful APIs (Application Programming Interfaces) to manage communication between IEGSA and its connected markets. As a backend component, the SITM lacks a dedicated user interface. These APIs within the SITM are responsible for transferring data that underpins all market integration processes within IEGSA.

The scalable and standardized design of these APIs enables agnostic connections to diverse market platforms, ensuring seamless data exchange. Consequently, IEGSA can exchange bids, merit order lists, and activation orders with all interconnected markets. This multi-market connectivity provides System Operators with a more holistic view of available offers and bids, ultimately enabling more efficient and secure grid management.

- The **Settlement Unit** module facilitates the financial settlement of all trades executed within IEGSA. Flexibility Service Providers (FSPs) can upload documents related to metered readings – either at the main meter or sub-meter level – along with the activated volumes for all metering points associated with the specific resource. This ensures accurate settlement for all metering points involved in the trade.

5.1.2.5. PLATOON Horizon 2020 project: Digital PLAtform and analytic TOOls for eNergy

PLATOON deployed cutting-edge solutions for distributed edge processing and data analytics. These advancements enabled optimized real-time energy system management, presented in a user-friendly manner for energy sector professionals. To facilitate secure multi-party data exchange and collaboration throughout the energy value chain, the project ensured data governance through IDS-based connectors.

PLATOON developed and utilized a COSMAG-compliant reference architecture. This architecture served as the foundation for building and deploying scalable and replicable energy management solutions. These solutions addressed the diverse needs of stakeholders across the energy sector value chain, ultimately contributing to: increased renewable energy consumption, enhanced smart grid management, improved energy efficiency, optimized energy asset management.

Figure 44 shows PLATOON´s reference architecture, and the following paragraphs describe the different layers[93].

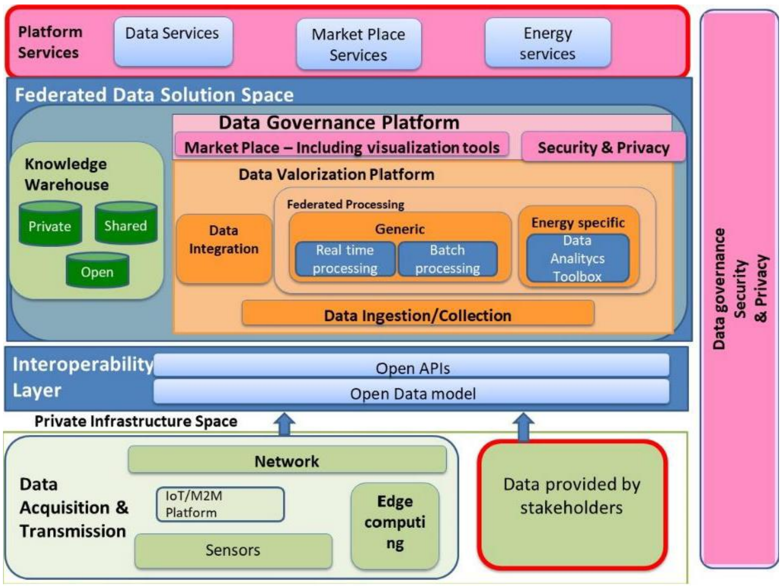

FIGURE 44 PLATOON´S REFERENCE ARCHITECTURE

[93] Description | PLATOON (platoon-project.eu)

- **Private Infrastructure space:** This layer comprises three main components:
    - **Physical infrastructure and data sources component:** This component encompasses all the data sources present at the physical locations of each pilot project or within an organization's operational environment. Examples include renewable energy production plants, individual buildings or building complexes, and individual devices like energy meters. This layer also incorporates historical data that an organization may have collected and currently uses for business operations. This data can include: real-time sensor data streams, historical data series from various sources, such as periodic sensor measurements or performance indicators collected over time, static data describing object characteristics relevant to the organization (e.g., building or plant specifications, device configuration parameters).
    - **External Data Sources /Open Data component:** This component incorporates all data sources that exist outside of an organization's own environment (i.e., beyond the PLATOON ecosystem) but are valuable for enriching the knowledge base. This external data can encompass various types of information, including: historical weather data series, weather forecasts, publicly available Open Data sets.
    - **Pilot IT Systems component:** This component encompasses all existing, organization-specific IT systems (proprietary or legacy systems) that manage operational and historical databases. These systems can handle various types of energy-related data, including information collected from: Internet of Things (IoT) devices, diverse energy infrastructure. Examples of such internal systems include: IoT gateways responsible for translating and adapting proprietary IoT protocols as well as SCADA-compliant platforms that provide data using dedicated legacy protocols. For technical reasons or due to company policies, these internal systems often represent the sole feasible interface for communication between devices and higher-level components within the PLATOON architecture.
- **Interoperability layer:** The interoperability layer plays a crucial role in bridging the gap between diverse data sources and downstream systems. Its primary function revolves around transforming collected data into a structure that facilitates efficient management and exploitation by these systems. This layer achieves this functionality through a series of key processes. Firstly, the interoperability layer boasts the capability to capture and manage a wide variety of data types. This heterogeneous data acquisition is accomplished through two key components: IoT Connectors and Data Connectors. IoT Connectors establish communication with physical devices such as sensors and embedded systems, facilitating data collection from the Internet of Things (IoT) environment. Data Connectors, on the other hand, are responsible for retrieving data from legacy or proprietary systems, ensuring comprehensive data acquisition. Secondly, the layer addresses the challenge of data interoperability through a process of Semantic Adaptation and Mapping. This process fosters a standardized understanding (semantics) of the collected data. The layer adopts established common semantic models, with concrete adaptations implemented through a dedicated component. Finally, the interoperability layer ensures data quality through Data Curation and Integration. This functionality establishes logical rules for data validation. This process identifies and filters out suboptimal data for processing, ultimately ensuring the ingestion and harmonization of high-quality data into a common language and format.
- **Federated Data Solutions Space:** This platform assumes responsibility for managing both historical and real-time data. It provides access to this data through standardized APIs for consumption by upper layers. The core components within this layer strive to establish a unified knowledge base. This knowledge base acts as a central repository for data collected and harmonized by the interoperability layer. Users can access this data using semantic federated queries, enabling them to retrieve information across diverse data sources seamlessly.

Furthermore, the data management layer recognizes the significant volume of data generated by the pilots. To address this challenge, the layer leverages specific big data technologies to ensure efficient data handling. Additionally, the layer incorporates a Context Broker, enabling real-time and context-aware data management through a publish-subscribe approach. This approach facilitates the dissemination of real-time data based on specific user or application requirements.

- **Platform Services:** The intelligence layer forms a cornerstone of the PLATOON architecture. This layer focuses on processing information received from lower levels to generate valuable insights and services. It encompasses a comprehensive suite of big data analytics and artificial intelligence techniques, capable of handling both real-time and batch processing tasks. A key component within this layer is the Data Analytics Toolbox. This toolbox will act as a central hub for all data analytics tools developed by project partners. This layer also includes the marketplace component which will be in charge of publishing and enabling search for different type of assets (including datasets, service and applications (e.g., data analytic tools) providing also functionalities to describe them through metadata that includes the properties of the assets and the way to access them. The marketplace will be the way in which pilots can share, with the rest of the ecosystem, data and applications that will be accessible through standard metadata description and API. The marketplace, depending on the specific case, can also enable additional functionalities related, for instance to the asset monetisation and transaction monitoring.
- **Security, Privacy and Sovereignty:** The security and privacy layer serves as the bedrock of trust within the PLATOON architecture. This cross-cutting layer plays a critical role in safeguarding the entire ecosystem. It achieves this by ensuring the security and privacy of all data and processes throughout the system. The layer accomplishes this mission through a combination of functionalities. Firstly, it implements robust authentication and authorization mechanisms. This guarantees that only authorized users and applications can access and interact with the system, preventing unauthorized access and potential misuse. Secondly, the layer prioritizes data confidentiality and integrity. This ensures that sensitive data remains protected from unauthorized access and maintains its accuracy during transmission and storage. Furthermore, the security and privacy layer empowers individuals through data usage control and personal data management functionalities. This grants users the ability to manage their personal data in accordance with relevant regulations, fostering trust and transparency within the system. Additionally, the layer establishes a logical connection with the specific security frameworks employed by the pilots' infrastructure. This integrated approach ensures that all architectural components operate within a secure and reliable environment. By implementing these comprehensive functionalities, the security and privacy layer safeguards the entire PLATOON ecosystem, fostering trust as a foundational principle.

5.1.2.6. OneNET Horizon 2020 project: One Network for Europe

The OneNet Network of Platforms layer prioritizes the seamless integration of external platforms, including those from Distribution System Operators (DSOs), market operators, and other data exchange entities, into the OneNet ecosystem. This integration leverages a fully decentralized approach, enabling direct peer-to-peer (P2P) interaction between individual systems (OneNet Participants) without the need for a central intermediary.

Within the OneNet Network of Platforms layer, the OneNet Connector stands as the most critical component. This software module facilitates the entire data exchange process. The OneNet Connector is a specialized instance of the OneNet Decentralized Middleware deployed within each platform, enabling effortless integration and collaboration between them. Following International Data Spaces (IDS) specifications, the Connector utilizes a Context Broker based on the FIWARE Orion Context Broker and NGSI-API. As illustrated in Figure 45, the Connector encompasses a configuration tool, a suite of interoperable APIs facilitating connection to existing platforms, applications, and services, alongside Data Harmonization functionalities[94].

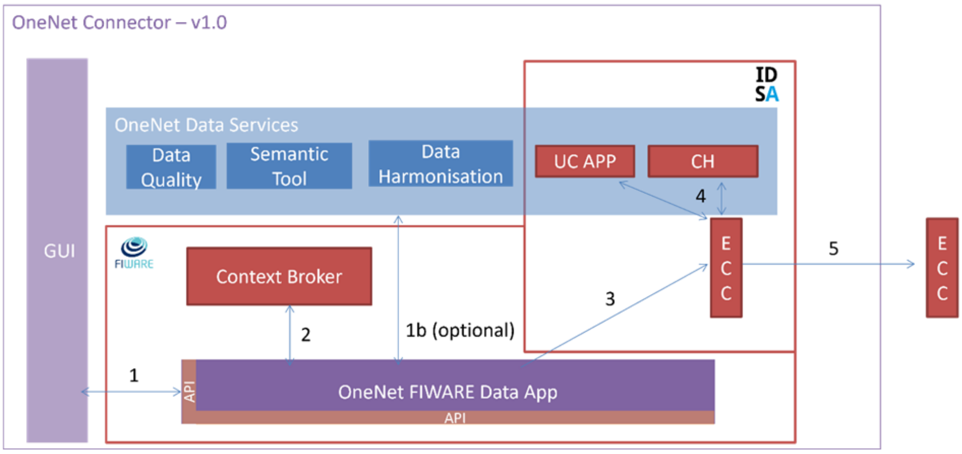

FIGURE 45 ONENET CONNECTOR ARCHITECTURE

The OneNet Framework layer is the core of the OneNet Architecture. It is composed of: OneNet Decentralized Middleware; OneNet Orchestration Workbench and OneNet Monitoring and Analytics Dashboard (Figure 46).

- **OneNet Middleware** enables a secure and reliable end-to-end data exchange between all the assets and components integrated in the OneNet Network. The Middleware also provides central features to all the actors like identity management, sources discovery, semantic annotation, vocabularies and ontologies.
- **OneNet Orchestration Workbench** aims to support data orchestration for evaluating performance and scalability of the AI, IoT and Big Data cross-platform services for market and grid operations. The workbench allows to integrate data coming from the OneNet Middleware and to implement a data pipeline orchestration.
- **OneNet Monitoring and Analytics Dashboard** can be considered an administrative and configuration tool. In addition to having an easy integration with the OneNet Orchestration Workbench and OneNet Middleware, this tool provides the data-analytics dashboard, the monitoring and alerting dashboard for data processes and platform integrations, the user-friendly selection of data sources and services from the catalogues.

[94] onenet-project.eu/wp-content/uploads/2022/12/OneNet_D5.2_v1.0.pdf

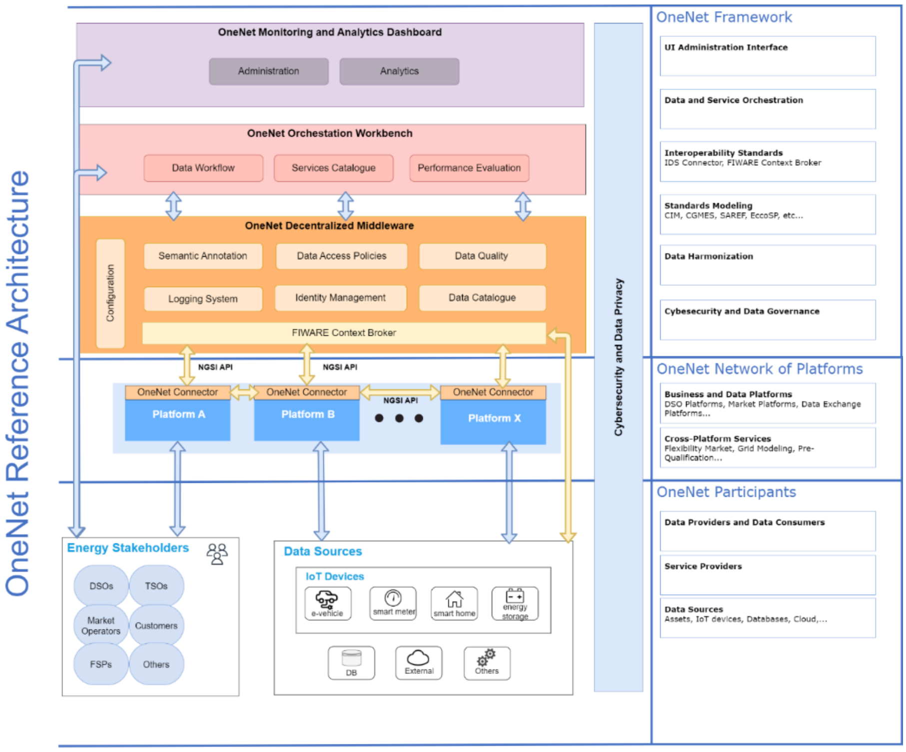

FIGURE 46 ONENET REFERENCE ARCHITECTURE

5.1.2.7. The BRIDGE Data Exchange Reference Architecture (DERA)

The BRIDGE initiative, launched by the European Commission, brings together 64 Horizon 2020 projects focused on Smart Grids, Energy Storage, Islands, and Digitalization. By sharing practical experiences, feedback, and lessons learned, these projects work to identify common challenges faced in real-world demonstrations. This collaborative effort aims to develop a comprehensive understanding of cross-cutting issues hindering innovation. Ultimately, BRIDGE seeks to provide policymakers with clear and unified recommendations, strengthening the impact of these projects and accelerating progress.

The BRIDGE Initiative facilitates ongoing knowledge exchange between participating projects. This collaboration aims to achieve a unified perspective on project outcomes and recommendations for utilizing research findings. This objective is pursued through four distinct Working Groups, each addressing a core area:

- Data Management
- Business Models
- Regulations
- Consumer and Citizen Engagement

The Data Management Working Group spearheads the development of the BRIDGE Data Exchange Reference Architecture (BRIDGE DERA). This framework builds upon the Smart Grid Architecture Model (SGAM) and incorporates insights gleaned from surveys administered to a wide range of projects and initiatives. These surveys encompass both sector-specific efforts, such as INTERRFACE and EEBUS, and cross-sector projects like InterConnect and OpenDEI (Figure 47)[95].

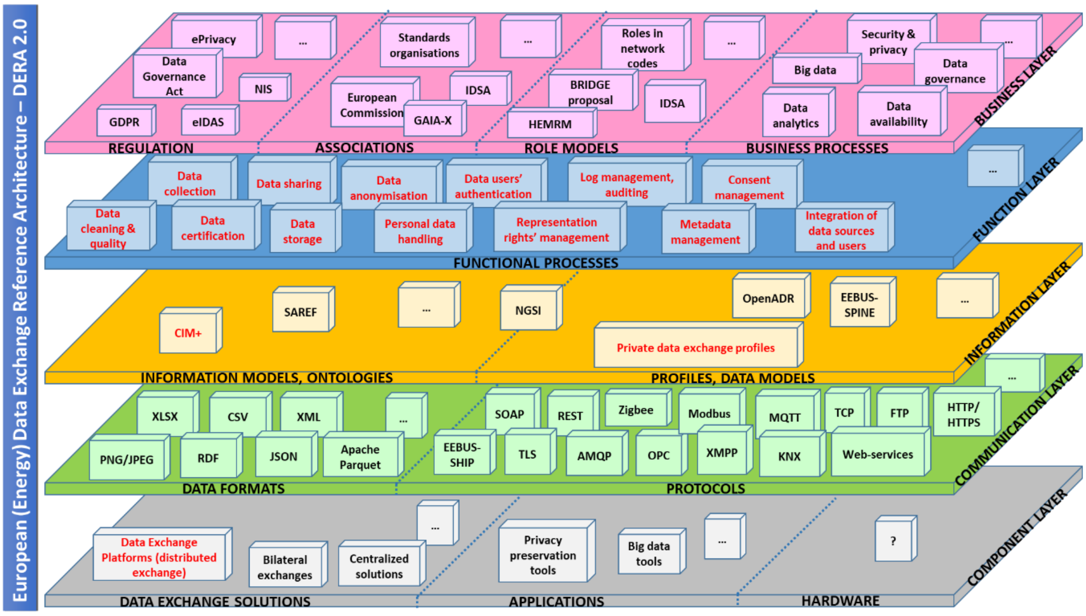

FIGURE 47 THE BRIDGE DERA

DERA 2.0 leverages the Smart Grid Architecture Model (SGAM) to establish a foundation for interoperability. Building upon this core, DERA 2.0 defines sub-layers within a topmost **'Business Layer'**. These sub-layers address various aspects of data exchange:

- **Regulation**: This sub-layer encompasses both sector-specific and cross-sectoral European Union regulations that govern data exchange.
- **Associations**: Here, relevant entities like the European Commission or GAIA-X are identified.
- **Role Models**: This sub-layer defines various roles within the architecture through dedicated models. For instance, the Harmonised Electricity Market Role Model (HEMRM) establishes data-related roles such as Data Provider and Consent Administrator.
- **Business Processes**: This sub-layer outlines common generic processes, along with those specific to the electricity sector and processes that span across sectors.

The **'Function Layer'** encapsulates a suite of functions and services identified through the analysis of use cases associated with the examined initiatives. This layer encompasses both sector-specific processes, such as those related to grid monitoring and operation, and cross-sector functionalities, including data collection and consent management.

The **'Communication Layer'** facilitates seamless data interoperability between components based on the specific use cases and functionalities they support. This layer comprises two sub-layers:

- **Data Formats Sub-layer**: This sub-layer focuses on establishing a foundation for data exchange and typically employs generic, sector-independent formats such as XML and CSV.

[95] https://energy.ec.europa.eu/system/files/2021-06/bridge_wg_data_management_eu_reference_architcture_report_2020-2021_0.pdf.

- **Protocols Sub-layer**: This sub-layer governs the communication procedures between components. It incorporates both generic protocols, applicable across various sectors, and sector-specific protocols tailored to address specialized communication needs.

The final layer, the **'Component Layer'**, defines the physical distribution of system components. This layer is further divided into three sub-layers:

- **Data Exchange Solutions Sub-layer**: This sub-layer focuses on enabling distributed data exchange and ensuring interoperability between disparate platforms.
- **Applications Sub-layer**: This sub-layer encompasses both electricity-specific components, such as Supervisory Control and Data Acquisition (SCADA) and Energy Management Systems (EMS), and cross-sector applications, with a particular emphasis on data management solutions like privacy-preserving tools and big data analytics.
- **Hardware Sub-layer**: This sub-layer addresses the physical hardware components required for system operation. The specific hardware needs will vary significantly depending on the use case.

The **BRIDGE Data Exchange Reference Architecture (DERA)** encompasses a comprehensive framework for data exchange, addressing not only electricity-specific aspects but also cross-sector functionalities. Within this architecture, Data Space Connectors primarily reside within the Data Exchange Solutions sub-layer. However, for effective data exchange, data formats, models, and protocols defined in the upper layers are equally critical considerations.

While semantic interoperability is not explicitly addressed by DERA, its importance is acknowledged, particularly in projects like InterConnect that were examined during the architecture's development. Furthermore, DERA focuses on technical considerations within the lower layers, while other data space initiatives, such as GAIA-X and IDSA, address business layer aspects. For instance, the IDSA Role Model is incorporated within the corresponding sub-layer depicted in Figure 47.

The **BRIDGE initiative** fosters collaboration across various EU projects, aiming to identify and establish synergies and common solutions in the domain of data exchange. While the BRIDGE Data Exchange Reference Architecture (DERA) serves as an abstract framework, it is not intended for direct practical implementation. However, DERA plays a valuable role by providing a reference point for ongoing research projects. Many such projects leverage DERA as a foundation when formulating their own architectures and subsequently designing systems tailored to their specific use cases.

5.1.2.8. BD4NRG Horizon 2020 project

BD4NRG is a European Union initiative funded by Horizon 2020. This project focuses on creating a system where data and services can be easily shared within the energy industry. They aim to achieve this by bringing together different existing methods and making them work seamlessly, allowing the system to be used for many different purposes.

To support the 12 different BD4NRG pilots across 9 countries, the project developed a reference architecture in two phases:

- **Analysis and Evaluation:** First, they examined existing models (BRIDGE, GAIA-X, IDS RAM and FIWARE RA) to understand their strengths and weaknesses.
- **Integration:** They then combined the best aspects of these models to create a unified system that could handle all the project's use cases.

This initial design was finalized in July 2022 based on insights from the running pilots and the technical progress of the project[96].

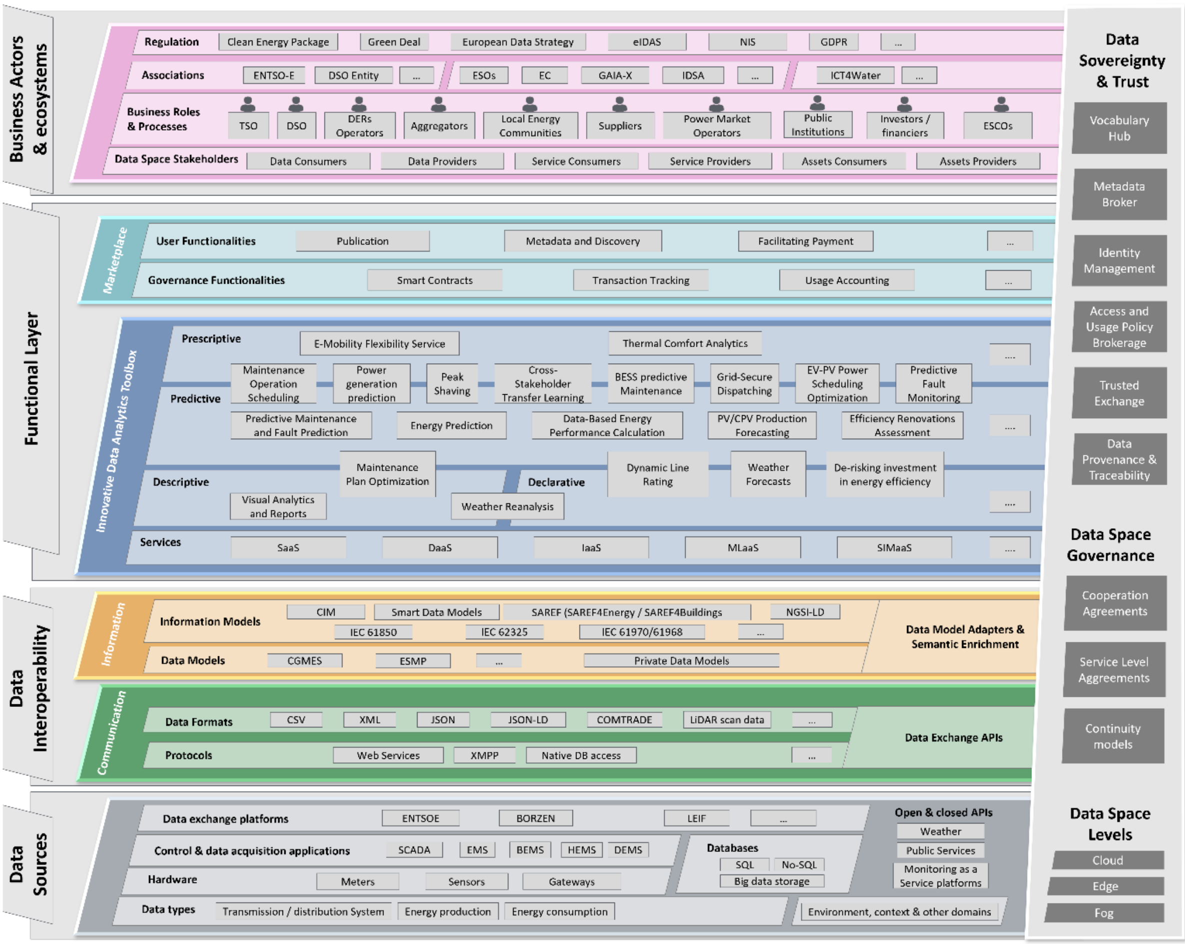

FIGURE 48 THE BD4NRG RA

As illustrated in Figure 48, the BD4NRG reference architecture leverages the layered structure of the BRIDGE Reference Architecture (RA). However, it is adapted to address the specific requirements of the BD4NRG project. It also incorporates valuable concepts from other relevant approaches, including IDSA, GAIA-X, and FIWARE. The architecture comprises four main layers, along with a cross-cutting pillar that addresses aspects relevant throughout the entire system.

Within the BD4NRG reference architecture, the **Data Sources Layer** serves the critical function of identifying and comprehending the Big Data originating from a diverse range of sources. This layer encompasses:

- Energy sensors and meters
- Data monitoring and acquisition platforms (e.g., SCADA systems, Building Energy Management systems)
- Databases containing historical or real-time data

[96] bd4nrg.eu/sites/default/files/2023-06/BD4NRG Reference Architecture First Version 1.0.pdf

- Smart grid data exchange platforms
- Cross-domain information, including environmental data and information from public administration services (e.g., energy performance contracts)

In essence, this layer aligns with the Component Layer of the BRIDGE architecture, encompassing all data-generating hardware, applications, and platforms.

Building upon the data sources, the **Data Interoperability Layer** plays a critical role in ensuring seamless information exchange. This layer focuses on two key aspects:

- Communication Protocols and Data Formats: It identifies the communication interfaces required to interact with the various data sources and the corresponding data formats they utilize.
- Data and Information Models: It provides a standardized set of data and information models that can be either followed directly or used for data transformation. This promotes interoperability, guaranteeing that data can be exchanged and utilized effectively across the system.

In essence, this layer merges the functionalities of the "Communication" and "Information" layers within the BRIDGE architecture.

Within the BD4NRG reference architecture, the **Functional Layer** comprises two distinct sublayers:

- Innovative Data Analytics Toolbox Sublayer: This sublayer houses the various analytical functionalities being developed throughout the BD4NRG project. These functionalities will be offered for exchange through the marketplace layer.
- Marketplace Sublayer: This sublayer serves as the critical interface between the BD4NRG functionalities and the "Business Actors & Ecosystems" that utilize them. It encompasses tasks such as: a) Smart Contracts: Management of automated agreements governing transactions within the marketplace, b) Transaction Tracking: Monitoring and recording the movement of functionalities and data within the marketplace, and c) Payment Facilitation: Enabling secure and efficient financial transactions between participants.

Furthermore, the Marketplace Sublayer is itself divided into two sections:

- User Functionalities: This section provides a direct interface for platform participants to interact with the available functionalities.
- Governance Functionalities: This section offers support for the internal operations and management of the Marketplace itself.

The **Business Actors and Ecosystems Layer** serves the crucial function of identifying the various stakeholders who participate within the BD4NRG data analytics ecosystem and the corresponding energy data spaces. This layer encompasses a diverse range of actors, including:

- Data Providers: Organizations that contribute data to the ecosystem.
- Analytics Services Users / Data Consumers: Stakeholders who utilize the available analytical functionalities.
- Analytics Applications Providers: Developers who create and offer analytical tools within the marketplace.
- Data Space Enablers and Platform Providers: Organizations that provide the technical infrastructure and tools necessary for data space operations.

It's important to note that an organization or business role within the broader energy ecosystem can occupy multiple roles within a data space. For instance, a Transmission System Operator (TSO) could act as both a data provider and a consumer of analytics services simultaneously.

Completing the BD4NRG reference architecture is a pillar located on the right-hand side, encompassing three cross-cutting sections that permeate the entire system:

- **Data Space Governance**: This section emphasizes the importance of establishing agreements among the various Business Actors and Stakeholders participating within the data ecosystem. These agreements will guide data usage and ensure responsible data management practices.
- **Data Sovereignty & Trust**: This section focuses on mechanisms that underpin data security and user confidence. It encompasses tasks like Identity Management and Data Provenance tracking, along with concrete modules such as a Vocabulary Hub and a Metadata Broker. These elements, which leverage concepts from FIWARE and IDSA, facilitate data traceability and ensure data integrity. Details regarding interoperability specifications can be found in Deliverable 2.6 of the project.
- **Data Space Levels**: Finally, this section acknowledges the potential for deploying the architecture across different computing environments. It identifies three potential "Data Space Levels": Cloud, Edge, and Fog. The selection of the most suitable level may vary depending on specific system requirements and data processing needs.

As of this report's publication date, the practical implementation of the BD4NRG system and its architecture remains ongoing. The development process is closely coordinated with the aforementioned pilot projects and will directly integrate components from both IDSA and FIWARE.

5.1.3. Discussion & conclusions

The concept of Data Spaces is gaining traction as a means to facilitate secure and controlled data exchange between businesses and individuals. This collaborative approach fosters innovation and unlocks the full potential of data by enabling cross-organizational, cross-sector collaboration. However, the initial landscape was fragmented, with various initiatives like IDSA, GAIA-X, and FIWARE developing their own technical specifications and frameworks. This fragmentation threatened to create a technological labyrinth for businesses seeking to participate in Data Spaces.

The Data Space Business Alliance (DSBA), formed by the aforementioned Data Space initiatives, aims to bridge this gap by achieving technical convergence. This convergence effort strives to establish a common reference framework, a unified set of technical specifications that ensure interoperability between different data space implementations. The approach focuses on developing a Minimum Viable Framework (MVF) that addresses three key pillars:

- **Data Interoperability:** This pillar ensures seamless data exchange between different domains, regardless of the underlying technology used. Imagine data speaking a common language, allowing for smooth communication and collaboration.
- **Data Sovereignty and Trust:** This aspect prioritizes data owner control. Businesses and individuals can define the terms and conditions for data usage, ensuring they retain sovereignty over their valuable assets.
- **Data Value Creation:** The ultimate objective is to unlock the potential of shared data. By enabling the combination of data, businesses can generate innovative products and services, fostering a thriving data-based economy.

The DSBA's technical convergence hinges on the development of crucial components:

- **Data Space Connectors:** These connectors act as gateways between different domains/participants/services, facilitating communication and data transfer.

- **Data Space Registry**: A central point for discovering and connecting with relevant Data Spaces is envisioned. This registry will be crucial for businesses seeking to participate in the Data Space ecosystem.
- **Federated Services**: Open-source components will power essential services within Data Spaces, such as marketplaces for data exchange and metadata brokers for data discovery.

The technical convergence pursued by the DSBA offers several compelling benefits:

- Reduced Development Costs and Time: By providing a standardized framework, the DSBA aims to streamline the creation and operation of data spaces, reducing the burden on businesses.
- Enhanced Interoperability: The common reference framework ensures seamless data exchange across different data space implementations, fostering collaboration and innovation.
- Simplified Adoption: Businesses can more easily participate in the data space ecosystem due to the reduced complexity and standardized approach.

The DSBA has made significant progress, releasing initial documents outlining the technical convergence vision and approach. These documents are open for discussion and refinement by member organizations. While still under development, this initiative represents a major step towards a unified and efficient data space landscape.

5.2. Motivation behind Data Spaces for iGFBs

The changing function of buildings in the power grid

Buildings are major energy consumers, placing a significant strain on the modern power grid. In developed countries, they can devour 30% to 40% of the total primary energy. WeForming investigates the potential for buildings to transform from passive consumers to active contributors to a more efficient and reliable power grid, thus intelligent Grid Forming Buildings. Traditional building electricity demands, such as lighting, miscellaneous appliances, and heating, ventilation, and air conditioning (HVAC) systems, present opportunities for manipulation. This manipulation aims to adjust electricity consumption to desirable levels and times while maintaining occupant comfort and productivity. Demand response (DR) programs, a well-established strategy employed by grid operators, leverage these opportunities to balance supply and demand.

The landscape is further evolving with the application of distributed energy resource (DER) technologies. Solar photovoltaics (PV), combined heat and power (CHP), electric vehicles (EVs), energy storage, and microgrids empower active building loads. These active loads contribute by reducing overall demand and fulfilling energy, capacity, and ancillary service requirements. The rapid growth of DERs necessitates advancements in utility market mechanisms, prompting recent studies to explore innovative approaches. The global market for residential DERs is projected to experience an annual growth of 60 GW in 2021, with an upward trend anticipated for the coming decade. This growth is primarily driven by EV charging infrastructure and on-site solar generation.

Buildings' capacity to manipulate their energy consumption through reduction, shedding, shifting, modulation, or on-site generation using DERs is collectively referred to as demand flexibility or energy flexibility. This concept, illustrated in Figure 49, offers a glimpse into the future where buildings become active participants in the energy grid, fostering a more sustainable and efficient energy landscape (Li et al., 2021).

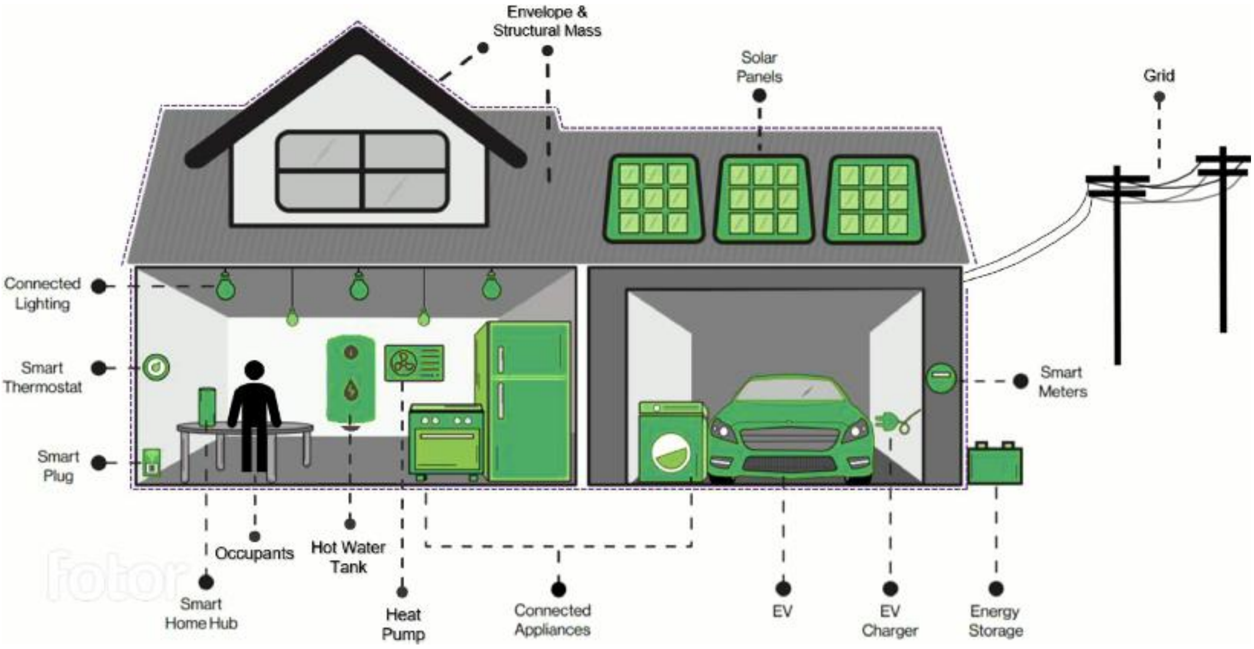

FIGURE 49 COMPONENTS OF A GRID-INTERACTIVE EFFICIENT RESIDENTIAL BUILDING (ADAPTED FROM LAWRENCE & VRINS, 2018))

In the past, maintaining equilibrium between electricity supply and demand has relied heavily on the supply side (Lawrence at al., 2018). This involves adjustments such as throttling power generation, activating backup generators, or importing electricity from interconnected utilities. However, a paradigm shift is underway with the emergence of flexible building operations. Buildings can now actively modify their power consumption in response to grid conditions or pricing signals. This power adjustment on the demand side is known as demand response (DR).

Local utilities and system operators play a crucial role in promoting energy flexibility through well-designed DR programs. These programs incentivize customers to alter their energy consumption patterns, ultimately contributing to a more balanced grid. There are two primary categories of DR programs offered by utilities: voluntary and involuntary.

Voluntary DR programs can be further classified based on the mechanism employed to trigger them. Price-based programs adjust electricity costs in real-time, while incentive-based programs offer rewards to customers who reduce consumption during peak periods. Voluntary DR events, typically initiated by utilities, independent system operators (ISOs), or curtailment service providers, encourage participants to temporarily adjust their electricity use. These programs can be automatic or manual, and cater to diverse participants.

However, in extreme circumstances where voluntary DR proves insufficient, involuntary measures may become necessary. These measures involve planned, rolling blackouts implemented during peak demand periods to ensure grid stability. Table 8 summarises the most well-known schemes:

TABLE 8 SUMMARY OF TYPES OF DR PROGRAMS

Program	Definition	Trigger	Manual	Voluntary	Participants
Time-of-Use (TOU)	Utilities engage customers with time-based electricity prices for each period (e.g., on-peak vs. off-peak)	Price	yes	yes	residential, commercial, industrial
Critical Peak Pricing (CPP)	Utilities substantially raise the electricity price during a specified time period	Price	yes	yes	residential, commercial, industrial

	(e.g., hottest hours in a summer weekday)				
Real-time Pricing (RTP)	Utilities adjust electricity price over short time intervals (e.g., hourly) to invoke customer power demand changes	Price	yes	yes	residential, commercial, industrial
Variable Peak Pricing (VPP)	A combination of TOU and RTP where different pricing periods are predefined, but the price for on-peak periods varies by grid conditions.	Price	yes	yes	residential, commercial, industrial
Peak Time Rebates (PTR)	Utilities refund customers during pre-specified peak time periods based on the demand reduction relative to what the utilities expected the customer to consume.	incentive	yes	yes	residential, commercial, industrial
Direct Load Control (DLC)	Utilities directly control the operation of some customer equipment during peak demand hours, and offer customers some payment incentives.	incentive	no	yes	residential
Capacity Market Program	Participants are paid to be on call in exchange for agreeing to reduce load to certain levels during special events.	incentive	yes	yes	commercial, industrial
Interruptible/ Curtailable Service	Participants receive payments for any reduction in their demand when needed, and are penalized if they do not reduce their demand when required.	incentive	yes	yes	commercial, industrial
Ancillary Service (A/S) Market Program	Independent system operators (ISOs) allow participants to bid load curtailments in electricity markets as operating reserves.	incentive	yes	yes	commercial, industrial
Demand Bidding/Buy Back (DB)	ISOs encourage participants to bid load reductions at a price at which they are willing to be curtailed.	incentive	yes	yes	commercial, industrial
Emergency Demand Response	Utilities provide incentives in exchange for voluntary load reduction during special events.	incentive	yes	yes	commercial, industrial
Rolling Blackout	Electricity delivery is halted in different parts of the distribution region during different time periods to avoid a total power outage due to insufficient supply in extreme conditions.	event	no	no	n.a.

Traditionally, demand response (DR) programs have primarily targeted large commercial and industrial customers due to the scale of their energy consumption. However, with advancements in technology, participation is expanding to encompass smaller commercial and even residential customers. The aggregation of flexibility from distributed small-scale devices increases the total amount of usable energy and the general usefulness of the devices.

Enhanced Building-to-Grid service integration via interoperable design

The rise of distributed renewable energy sources, characterized by their intermittent nature (e.g., fluctuating wind and solar production), presents significant challenges for grid operators in maintaining grid stability. The unpredictable short-term production of these sources necessitates increased flexibility in both energy consumption and production. **Additionally, the anticipated active participation of**

buildings in the power grid, encompassing also the offering of electrification/charging services to other buildings and users, **will necessitate the integration of a diverse array of devices, systems, and user types.** Figure 50 depicts the evolving relationship between buildings and the power grid. The illustration demonstrates a shift from a unidirectional flow of energy, where buildings solely consume power from the grid to a more dynamic system. **In this advanced model, buildings (now iGFBs) can not only draw upon the grid but also contribute to it by offering flexibility in their own energy consumption or even by directly supplying power back to the grid or to other buildings**.

To address the above challenges and mitigate grid congestion or imbalance, a paradigm shift is crucial. **This shift requires real-time communication between energy consumers and producers**, ranging from individual residences to large industrial facilities. **This two-way communication empowers grid operators and participating entities to adapt and react to fluctuations in energy supply and demand**, ensuring a more balanced and resilient grid. To achieve this effectively, seamless and frictionless two-way communication between all participants/elements is of paramount importance.

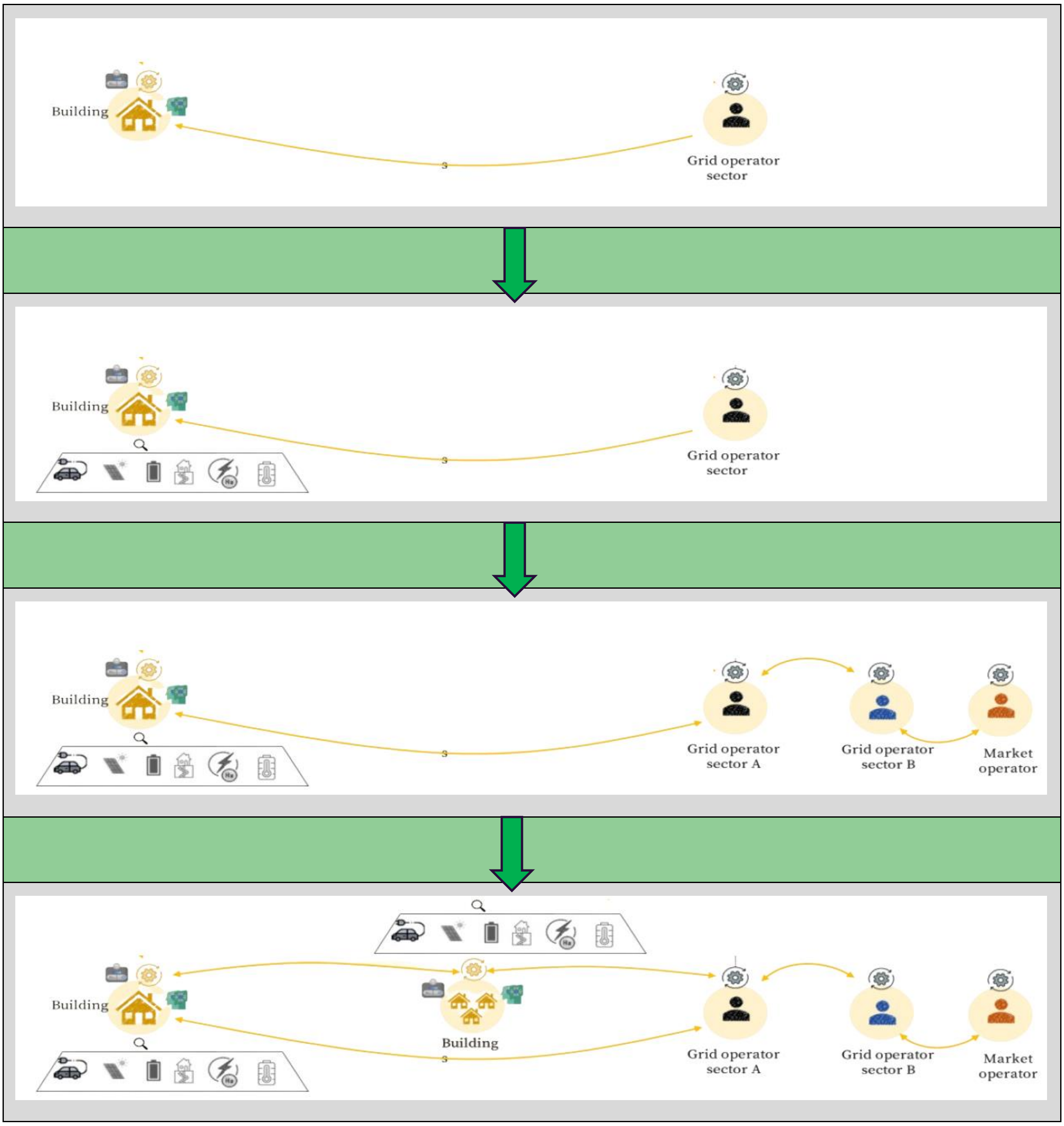

FIGURE 50 EVOLUTION OF THE GRID FORMING BUILDING

In the context of our research project, it is important to acknowledge the emergence of Data Spaces as secure digital environments facilitating two-way communication between organizations. Data Spaces enable controlled access and processing of various data types, **ranging from anonymized customer information to sensor data generated by equipment**. **Unlike traditional data integration methods, Data Spaces prioritize flexibility and adaptability. They achieve this by leveraging existing data matching and mapping techniques.** This allows for integration of information sources with inherent structural variations, ensuring usability.

The cornerstone of Data Spaces lies in its ability to achieve seamless data exchange. This interoperability is realized through two pillars.

The first pillar encompasses four facets:

- Data transport Interoperability: This facet focuses on the physical connections and signals that enable data transfer between systems e.g. through Modbus or Matter protocols[97].
- Syntactic Interoperability: This facet deals with the format of the data itself. Here, the focus is on ensuring data is received in a format that can be understood by the receiving system e.g. csv files[98]. Standardized data exchange formats are essential for achieving syntactic interoperability.
- Semantic Interoperability: This facet delves deeper, focusing on the meaning of the data. It ensures that the data being received aligns with a common understanding of the information shared. It lies in the promotion of common vocabularies and ontologies. These shared data definitions function as a universal language, enabling the effective interpretation and integration of data originating from diverse sources. Imagine a scenario where participants speak different data "dialects." Common vocabularies and ontologies bridge this gap, allowing for seamless communication and collaboration, see for example SAREF4ENER[99]. This facet delves deeper, focusing on the meaning of the data. It ensures that the data being received aligns with a common understanding of the data information model.
- Policy and organisational Interoperability: This facet addresses the regulatory and organizational policies that govern interoperation within a specific context. It focuses on conditions and controls for accessing and using data within the framework of these policies.

The second pillar supporting CEDS functionality is the establishment of robust governance mechanisms. These mechanisms define clear and comprehensive rules for data ownership, access control, and security. By establishing these clear rules, CEDS fosters trust amongst participants and ensures responsible data usage within the European data exchange ecosystem. In particular,

- Open Participation: CEDS are designed to be inclusive, welcoming participation from all organizations and individuals across Europe. This fosters a diverse and vibrant data exchange environment.
- Secure and Privacy-Preserving Infrastructure: CEDS prioritize data security and privacy. The infrastructure is designed to enable secure pooling, access, sharing, processing, and use of data, all while adhering to stringent privacy-preserving measures.

97 Build With Matter | Smart Home Device Solution - CSA-IOT
98 Comma-separated values - Wikipedia
99 SAREF for Energy Flexibility (etsi.org)

- Fair and Transparent Access: Clear and practical structures govern data access within CEDS. These structures ensure fair, transparent, proportionate, and non-discriminatory access rules. Well-defined and trustworthy data governance mechanisms underpin these access rules.
- Alignment with EU Values and Data regulations: CEDS operate within the framework of EU regulations and values. This includes a strong focus on protecting personal data, consumer rights, and fostering fair competition within the European data market.
- Flexible Data Sharing: Data holders within CEDS have the autonomy to decide how their data is shared. They can grant access to specific data sets, personal or non-personal, while also having the option to make their data available for free or for compensation. This flexibility caters to diverse data sharing needs within the ecosystem.

5.3. The Value Proposition of Data Spaces for iGFBs

In the following we highlight the main value propositions of Data Spaces for iGFBs:

5.3.1. Sovereign data sharing between iGFB Data Space participants – Protection of personal and sensitive data

On the one hand, organisations, companies and individuals increasingly need to exchange data in business ecosystems; on the other hand, they feel they need to protect their data more than ever before, since the importance of data has grown so much. Several recent data scandals involving the breach of personal and organisational data without the consent of the users have underlined the importance of data usage control. In a recent study conducted by Fouad et al. (2022) uncontrolled data usage and the fear unauthorised access to personal and sensitive data has been identified as one of the main obstacles towards the development of smart energy services. Data sovereignty refers to the concept that organizations, governments, and individuals have control over their data. It encompasses the ability to self-determine how and which data is collected, stored, shared, and used by others (Figure 51). It refers to the ability to monitor when and where data were shared and to perform an independent audit when necessary[100].

[100] Self-sovereign identity: Data sovereignty in the digital world (bundesdruckerei.de)

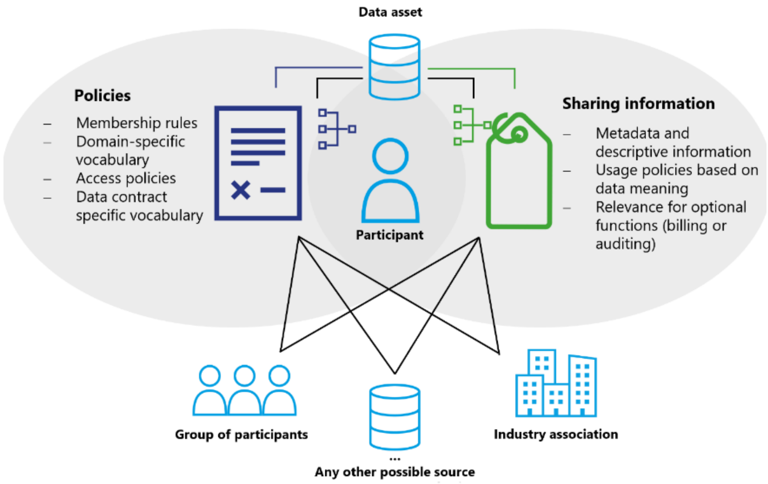

FIGURE 51 TRUSTED AND STRUCTURED RELATIONS BETWEEN DATA SPACE PARTICIPANTS

Three indicative examples that show the potential of sovereign data sharing for iGFBs are:

- Consent-based sharing for personalized recommendations: Imagine a platform where you securely share anonymized data on your energy usage patterns (e.g., peak hours, appliance usage). The energy service company can analyze this data (with your consent) alongside broader trends to recommend personalized energy-saving strategies. This could include suggesting time-of-day pricing plans or smart home devices that fit your specific needs.
- Collaborative optimization for renewable energy: In a community with a growing share of solar panels, individuals could choose to share anonymized data on their solar energy production. The energy service company, with user consent, could aggregate this data to optimize grid management. This could involve strategically shifting power loads or even enabling peer-to-peer energy trading within the community.
- Data marketplaces for energy innovation: Individuals could opt into secure marketplaces where they contribute anonymized or aggregated energy usage data. Researchers, startups, or even other energy companies could then access this data (with user consent and anonymization) to develop new energy-saving technologies or services. Users would benefit from being part of the solution and potentially share in any profits generated by the data.

5.3.2. Peer to Peer data sharing between iGFB Data Space participants. Data reside at their original location/ Collaboration based on Metadata

Our research project proposes the concept of federated data sharing following the IDS paradigm (Figure 52). Unlike traditional methods that involve centralized data storage, federated sharing allows data to reside at its original location while enabling collaborative analysis across multiple institutions. This approach offers significant advantages in terms of data security, privacy, and efficiency. In contrast to traditional data warehousing, where data is physically transferred and stored in a central repository, federated data sharing utilizes a virtual layer that integrates only metadata from various sources. This virtual layer acts as a unified interface, allowing authorized users to query and analyse data across disparate systems without the need for data movement. If data need to be moved this happens through peer-to-peer interactions. This distributed approach minimizes the risk of data breaches and unauthorized access, as sensitive information remains within the control of the originating organization[101].

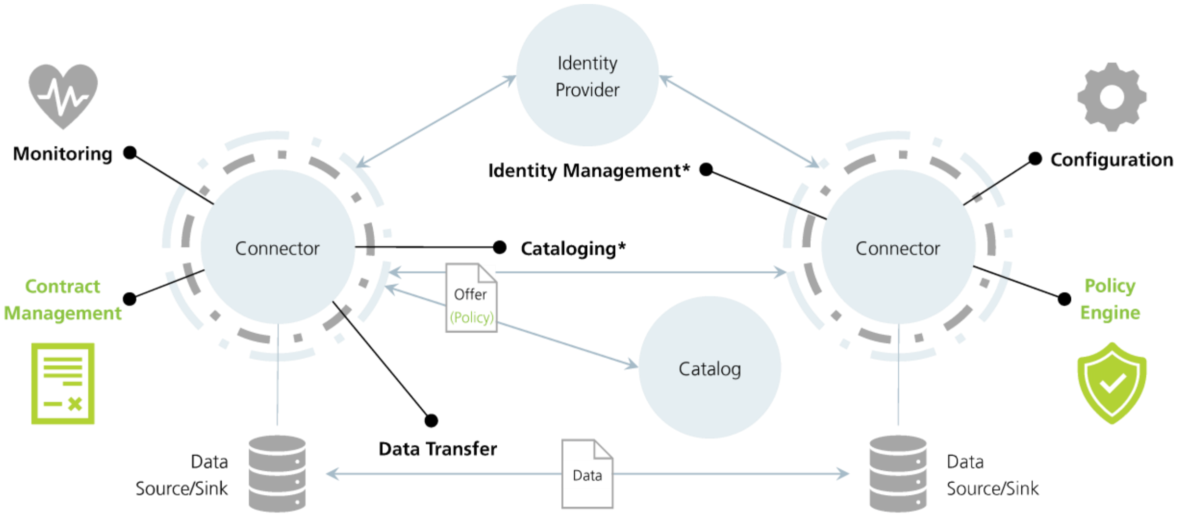

FIGURE 52 WEFORMING PEER TO PEER DATA SHARING USING (*CENTRAL) CATALOGING

The core strength of federated data sharing lies in its ability to balance collaboration with data privacy and security. By keeping data in its original location and employing robust access control mechanisms, federated systems ensure that only authorized users can access specific data subsets for predefined analytical purposes. This fosters trust and collaboration between institutions, including individual peers, that might otherwise be hesitant to share sensitive data due to privacy regulations or security concerns.

It's important to distinguish federated data sharing from pure peer-to-peer networks (e.g. Blockchain), which may lack the robust security and access control mechanisms that federated systems provide. Federated data sharing offers a more structured and secure environment for collaborative analysis, even when facilitating peer-to-peer interactions.

Three indicative examples that showcase the advantage of federated data sharing for iGFBs are:

- Predictive Maintenance with Anonymized Sensor Data: Building owners can deploy various sensors in their facilities to monitor equipment health (e.g., sensors for HVAC systems). Federated learning can be used on anonymized sensor data from multiple buildings (owned by different companies). The model, hosted by a neutral party e.g. maintenance company, can learn patterns that predict equipment failure without revealing any specific details about individual buildings or sensor readings. This allows companies to benefit from collective insights for predictive maintenance without compromising sensitive information about their own equipment or operations.
- Benchmarking Energy Efficiency without Sharing Raw Data: Companies can participate in federated learning models to benchmark their buildings' energy performance against anonymized data from similar buildings. The model wouldn't reveal raw energy consumption figures but would instead output insights like percentile rankings or identify areas for improvement compared to the anonymized group. This allows companies or individuals to understand their relative efficiency without revealing confidential details about their energy usage patterns.
- Building automation systems (BAS) manage various building functions like lighting and temperature control. Companies can share anonymized rules and algorithms used in their BAS systems through

[101] internationaldataspaces.org/wp-content/uploads/IDS-Reference-Architecture-Model-3.0-2019.pdf

federated learning. The model could learn best practices for optimizing building operations without revealing the companies' proprietary control logic. This allows for collaborative improvement of building automation strategies while protecting intellectual property.

As our research progresses, we will delve deeper into the technical aspects of federated data sharing, exploring specific protocols that enable secure and efficient peer-to-peer data access and analysis within the federated framework. We will also investigate the potential challenges associated with incorporating peer-to-peer interactions, such as ensuring data consistency, optimizing query routing, and maintaining trust between participating peers. By understanding both the advantages and limitations of this approach, we aim to contribute to the development of robust and secure federated data sharing frameworks for iGFBs that can unlock the full potential of collaborative data analysis, including peer-to-peer interactions.

5.3.3. Inclusive Power Demand – Response (DR) programs for iGFBs

Power demand response (DR) programs help manage electricity grids by influencing consumer behaviour. There are two main categories with different communication needs:

- Price-Based Programs (Implicit DR): Electricity prices fluctuate based on real-time supply and demand. Higher prices during peak hours signal consumers to reduce usage (e.g., time-of-use tariffs). For this type of program only limited two-way communication is needed. Utilities need to broadcast clear and timely price signals. Consumers don't require constant interaction but need education to understand price signals and adjust consumption accordingly.
- Incentive-Based Programs (Explicit DR): Utilities offer direct rewards (payments, rebates) to consumers who agree to curtail electricity use during peak periods upon request. In this program, two-way Communication is crucial. Utilities need to send event notifications specifying the time, duration, and desired level of load reduction. Consumers need to acknowledge receipt and confirm their ability to participate. In some programs, consumers might be able to submit bids indicating their desired compensation for reducing usage. Real-time feedback can be valuable, informing consumers of their actual load reduction and potential rewards. Here's a breakdown of the information flow for Incentive-Based DR:

  From Utility to Consumer:

  - Event notifications: Time, duration, and target load reduction for the DR event.
  - Price information: Compensation offered for different levels of load reduction (in some programs).
  - Real-time feedback: Consumer's current and historical load data during the event (optional).

  From Consumer to Utility:

  - Confirmation of participation: Consumer acknowledges they received the event notification and can reduce their load.
  - Bids (optional): Consumer proposes a desired compensation level for participating.
  - Load data (optional): In some programs, consumers may submit real-time data on their actual load reduction.

It is highlighted that individual households face limitations in directly participating with public network operators. The sheer volume of consumers and the complexities of two-way communication inherent in some DR programs, such as real-time event notifications and confirmation exchanges, would present a significant logistical challenge for utilities to manage effectively. Additionally, the individual impact on load reduction from a single household is typically minimal.

Aggregators play a critical role in bridging this gap and facilitating participation for small consumers. They act as intermediaries, establishing a communication channel between utilities and a large pool of geographically dispersed residential customers. This process begins with consumer enrolment, where aggregators actively recruit and register households in suitable DR programs, handling the initial enrolment process and associated paperwork. Subsequently, aggregators function as a communication bridge, receiving DR event notifications from utilities and translating this information into simpler, more readily understandable terms for their consumer base. They then manage the two-way communication with the utility on behalf of the entire pool they represent, ensuring timely confirmations and efficient data exchange. Figure 53 exemplifies the process (Lucas et al., 2019).

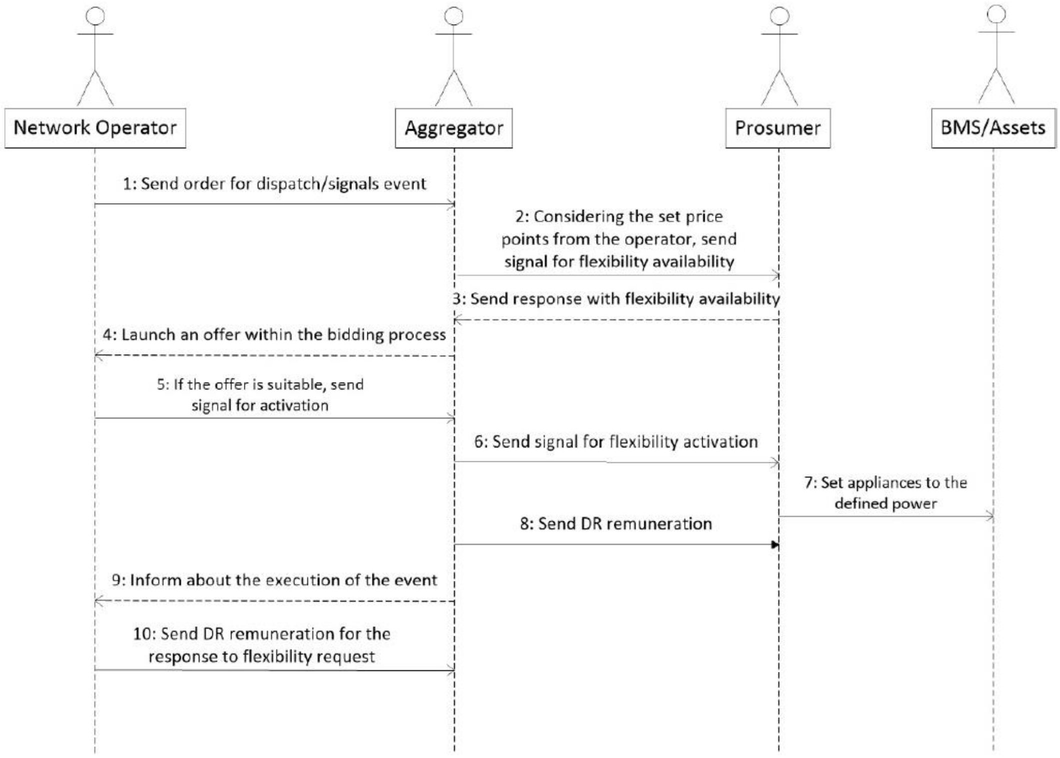

FIGURE 53 TWO WAY COMMUNICATION BETWEEN SMALL ENERGY CONSUMER/PROSUMER AND THE NETWORK OPERATOR

The concept of aggregation lies at the heart of the aggregator's value proposition. By combining the load reduction capabilities of all its enrolled consumers, the aggregator transforms a multitude of small contributions into a significant and measurable impact for the utility. This aggregated load reduction becomes readily apparent to the utility, making it a more valuable asset within the DR program framework.

Finally, aggregators play a crucial role in compensation distribution. They receive the total compensation from the utility for the collective load reduction achieved by their consumer pool. Following established protocols, the aggregator then distributes this compensation fairly among individual consumers based on their verified contribution to the overall program success.

While the role of aggregators is crucial in facilitating participation for small consumers in demand response (DR) programs, there are emerging alternative pathways for direct involvement. One such avenue lies in the growing trend of electrification and the services offered by iGFBs that are small to medium energy prosumers. An iGFB with excess generation capacity could sell electricity or EV charging services directly to neighbouring households during peak demand periods, potentially at a lower cost than the utility's peak rate. Another option is that of the micro-aggregator. By strategically managing their own generation, storage, and the consumption patterns of participating neighbours, the iGFB could collectively respond to DR events and earn compensation from the utility (Ali et al., 2021).

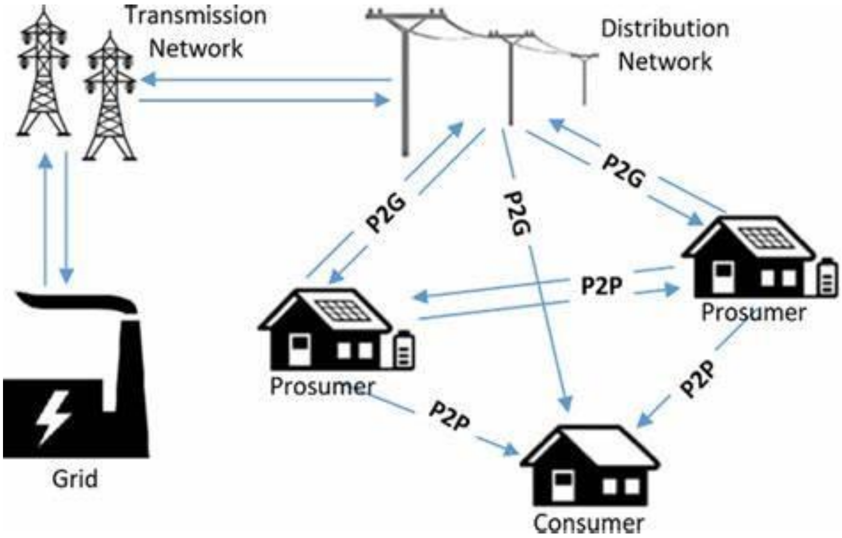

FIGURE 54 INCLUSIVE DEMAND RESPONSE PROGRAMS ALLOWING PEER TO PEER SERVICES

5.3.4. Establishing High-Quality Data and User-Friendly Service Catalogues for iGFB Data Spaces

The efficacy of data and service exchange within the iGFB Data Space hinges upon the development of high-quality data and user-friendly service catalogue vocabularies. Datasets lacking comprehensive qualitative and quantitative descriptions are rendered functionally unusable, as they impede the creation of dependable and economically sound services. This aligns with the established principle of "garbage in, garbage out," underscoring the critical role of data quality in achieving meaningful results.

iGFBs necessitate stringent data quality requirements, particularly concerning weather forecasting and power consumption predictions. The cornerstone for reliable applications, services, and digital contracts lies in the creation of iGFB vocabularies capable of comprehensively describing relevant datasets. The vocabularies should encompass both qualitative and quantitative aspects, including for example data origin, collection methodology, statistical significance, currency, and confidence level. Data origin details the source of the information, such as the specific sensors, devices, or simulations that generated it. The collection methodology provides a transparent and reproducible explanation of how the data was gathered. Statistical significance assesses the data's validity and representativeness, allowing users to gauge its reliability for drawing conclusions. Currency indicates the timeliness of the data, signifying whether it reflects current conditions or represents historical information. Finally, the confidence level measures the certainty associated with the data, enabling users to understand the potential for errors or inaccuracies.

By establishing these comprehensive data descriptions, the iGFB/WeForming Data Space will empower stakeholders to develop sophisticated analytical tools that can leverage data from diverse sources within the iGFB domain. Such tools can be harnessed to identify patterns within energy consumption data, uncovering trends and recurring patterns that provide valuable insights into building operations. Predictive analytics can forecast future energy demand with greater accuracy, enabling proactive energy management strategies. Additionally, data-driven recommendations can be generated to optimize energy usage across various carriers within an iGFB. For instance, business developers to combine weather data, occupancy information, and energy consumption data from multiple buildings. This comprehensive dataset would unlock the potential for developing highly accurate building energy models, ultimately leading to the creation of customized and improved energy services.

The **development of automated digital contracts for services, relies heavily on the precise description of data and service quality.** Furthermore, these **contracts must be presented in a user-friendly manner, ensuring human decision-makers can readily comprehend the terms, navigate the contract effectively, and ultimately make optimal choices**. **By implementing clear and standardized data vocabularies, and user-friendly human-machine interfaces**, **iGFB/WeForming Data Space** paves the way for the secure and efficient automation of **digital contracts** within the intelligent building ecosystem.

5.3.5. iGFB Business Ecosystem for Multi-Energy Systems leveraging evolving European initiatives

This research project investigates the current state of the art of data exchange for iGFBs. **Key European initiatives in this area is the development of Common European Data Spaces (CEDS) and the Smart Readiness Indicator rating scheme**.

CEDS aims to establish a unified data market within Europe, thereby unlocking the potential of data to contribute to both economic and societal progress across the continent. Aligning a business ecosystem with CEDS presents several advantages **because CEDS standardize data access and usage structures allowing participants from different Data Spaces (different sectors and domains) to collaborate with each other**. **CEDS presents a significant opportunity to optimize energy flexibility within Intelligent Grid Forming Buildings (iGFBs) that integrate Multi-Energy Systems. A standardized data exchange facilitated by CEDS fosters enhanced interoperability between various energy suppliers within an iGFB, such as electricity, heat, and gas. This interoperability can be achieved for example through the seamless sharing of a building's thermal energy needs and forecasts (**Figure 55**).**

Furthermore, the Smart Readiness Indicator rating of a building depends on its capacity to accommodate smart-ready services. The SRI rates the smart readiness of buildings in their capability to perform three key functionalities: a) optimise energy efficiency and overall, in-use performance, b) adapt their operation to the needs of the occupant and c) adapt to signals from the grid (for example energy flexibility). By performing an SRI assessment, it is possible to record building's data in a systematic and standardised way. **This standardized piece of information can become a valuable tool for the discovery of building energy flexibility potential as well as for match making energy services tailored to the needs of the user.**

Therefore, WeForming Data Space lays the foundation for the development of intelligent energy management platforms that can optimize energy consumption across diverse energy carriers. The target is to leverage real-time contextual data to dynamically adjust the utilization of each energy carrier. For example, the system could automatically increase district heating supply to compensate for fluctuations in solar energy availability, thereby maintaining energy efficiency.

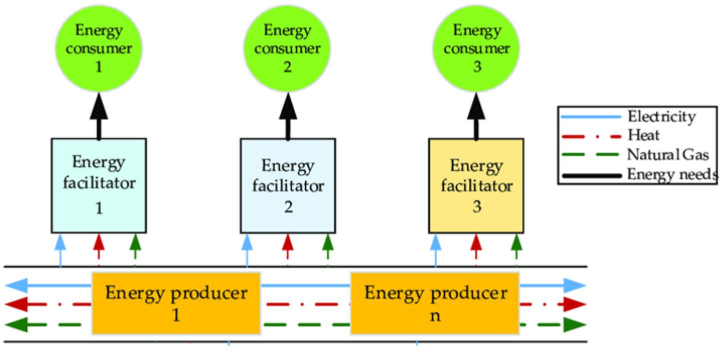

FIGURE 55 MULTI ENERGY CARRIER DATA SHARING FOR INCREASED BUILDING ENERGY FLEXBILITY

5.4. WeForming Reference Architecture

5.4.1. Functional requirements and specifications

The definition of the W-IBRA as a reference tool that can be broadly used, understood and reused beyond the frame of the project is quite challenging achievement. The current state of the project has attempted to provide a first iteration of the W-IBRA providing a hybrid version of reference and technical architecture that is presented in Section 5.4.3. To achieve this, the first months of the projects have been conducting the exercise of specifying end-users' requirements, system requirements both reflected on literature items from D2.1 towards the designation of functional requirements. Devising the W-IBRA there has been adopted a leverage of top-down and bottom-up approach the functional specification (Figure 56 COMPILATION OF BOTTOM-UP AND TOP-DOWN APPROACH ADOPTED ON W-IBRA INITIAL VERSION.). In Table 9, the two different approaches are discussed on five dimensions; in brief the bottom-up approach commences with the development of the most basic or low-level components and integrates them to form higher-level systems, whilst the top-down approach starts with the highest level of the system's architecture and progressively refines it into more detailed components and modules. Obviously, both approaches present advantages and disadvantages. In WeForming, there have been applied both on the W-IBRA specification and design as a matter of presenting clear vision and structured view of the entire system from the beginning as well as providing insights and technicalities on low-level component view (from the bottom-up approach).

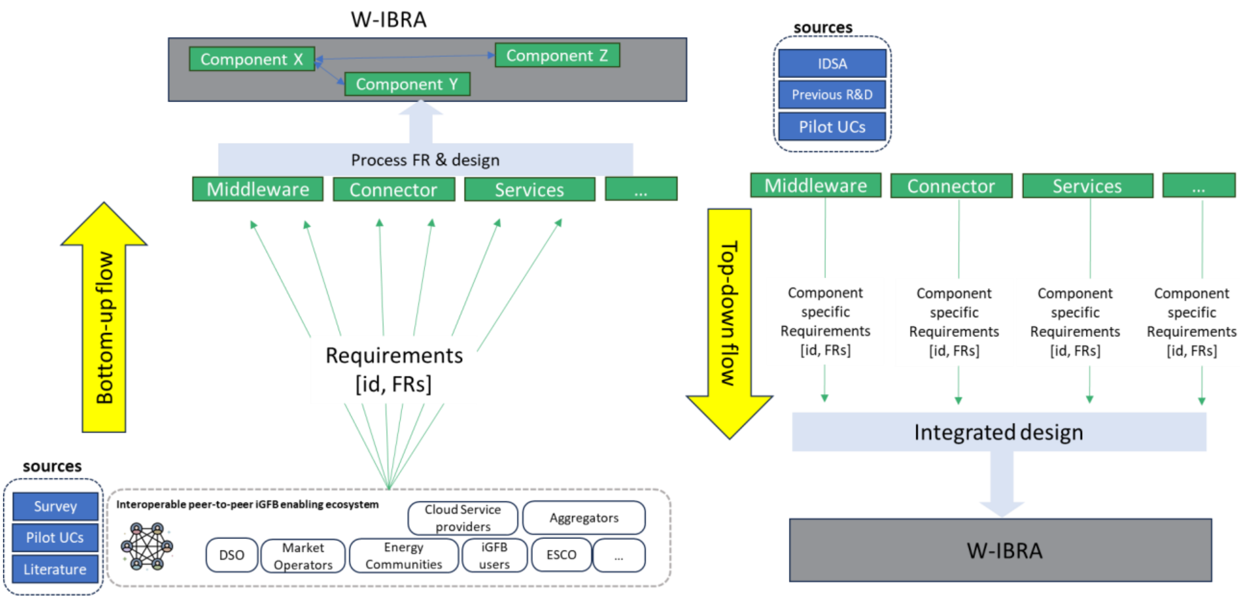

FIGURE 56 COMPILATION OF BOTTOM-UP AND TOP-DOWN APPROACH ADOPTED ON W-IBRA INITIAL VERSION.

TABLE 9 TOP-DOWN & BOTTOM-UP APPROACHES.

Aspect	Top-Down Approach	Bottom-Up Approach

Starting Point	**High-level architecture**	**Low-level components**
Design Focus	**Overall system design**	**Detailed component design**
Flexibility	**Less flexible to changes**	**More flexible to changes**
Integration	**Integration occurs later**	**Continuous integration**
Vision and Planning	**Clear overall vision from the start**	**Evolving vision with incremental steps**

For the bottom-up approach, available source that have been processed to provide system's and functional specifications have been the a) pilot BUCs, b) the content of D2.1 that established the SoTA analysis on the iGFBs. The bottom-up approach aims to establish a firm connection with pilot needs and broadly with end-user/iGFB requirements for the system specification. In the very next iterations, the co-creation survey results will provide end-users' requirements that will be incorporated into the W-IBRA.

On the top-down approach, commencing from IDSA Reference Architecture Model, focusing particularly on the process layer, functional specification have been detailed referring to the majority of modules/components that reside on the WeForming Middleware, and then detailed specification has been provided for each component including the so-called Cloud Operational Platforms that are developed in each Pilot, ML energy management application for multiple stakeholders, Digital Twins and the RT-controller.

Figure 55 presents a brief view of the process followed to devise the functional specifications following the system views. The detailed functional specifications list is presented on the

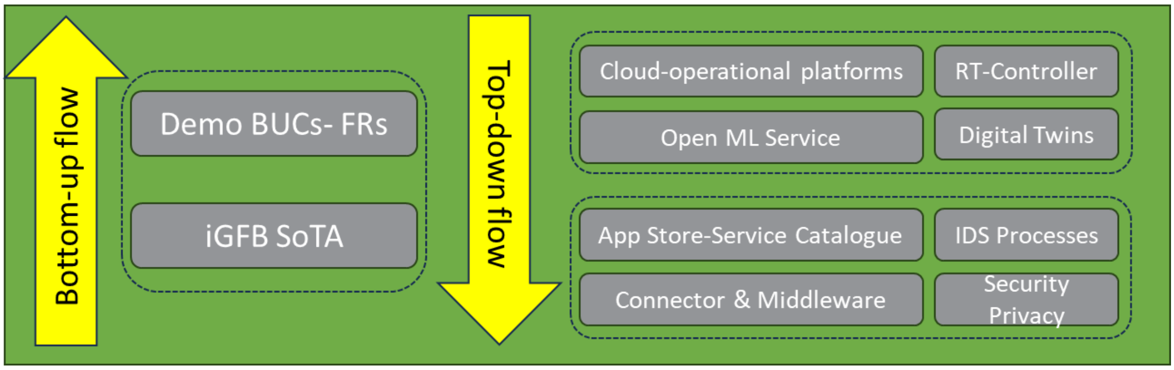

FIGURE 57 FUNCTIONAL SPECIFIATION APPROACH.

5.4.2. Data flow perspective of the WeForming Reference Architecture

Figure 58 depicts the WeForming reference architecture from a data flow perspective. It identifies the core components within an iGFB Data Space and elucidates the way data flow between them. The reference architecture adheres to the IDSA paradigm, which prescribes a limited set of role models: data consumer, data provider, and service/application provider (encompassing intermediaries, operators, and value-adding services).

Notably, a WeForming Data Space participant has the flexibility to assume the roles of data consumer, provider, and service provider depending on the specific use case. However, the underlying data sharing process remains consistent regardless of the assumed role. Within the WeForming Data Space, participants will engage through a designated Data Space connector (DS Connector). Recognizing the varied technical backgrounds and competencies of WeForming participants (encompassing the business layer), a dedicated user-friendly interface (GUI) will be employed to ensure a seamless and intuitive experience. This GUI will act as a central access point, simplifying interaction with the underlying Data Space connector for all participants. Data exchange within the WeForming ecosystem can occur through either manual initiation or automated processes. Automated data sharing might be facilitated by Internet of Things (IoT) devices or cloud-based interfaces (system layer). However, regardless of the chosen mode (manual or automated), human intervention remains paramount in determining the specific data to be shared ("what") and the appropriate sharing method ("how").

The structure of the proposed WeForming RA can be analysed as follows:

The **WeForming Services/Data Apps** layer can be further stratified into three distinct modules:

- **iGFB Building module**: This module encompasses the **Customer Energy Management** component or **Building Management Systems (BMS)**. This component is responsible for generating the iGFB's energy management schedule (plan/real-time control). The iGFB Building module includes also the **Resource Management or Building Automation System (BAS)** component that directly controls building devices and interfaces. For iGFB participants involving on-site renewable energy (RES) production, a microgrid control component is also included within this layer.
- **iGFB Operational module**: This module comprises all applications and services that govern the operation of the iGFB. These applications can be categorized into five functional groups: **measurement, forecasting, optimization, control, and abnormal operation detection**. The **measurement function group** monitors various sources of energy consumption and production within the building. This includes electricity use for lighting, heating, ventilation, appliances, and any on-site renewable energy generation like solar panels. The **forecasting function group** analyses historical energy consumption data and considers external factors like weather forecasts and occupancy schedules. This allows the iGFB to predict future energy demand with statistical confidence within the building. The **optimization function group** analyses the measured consumption data, the forecasted demand, and external factors like energy costs and grid stability. It then determines the most optimal strategy for energy use within the building. This strategy might involve reducing consumption during peak hours, utilizing on-site generation, or purchasing electricity from the grid. It may or may not utilize advanced Machine Learning and Artificial Intelligence algorithms. The **control function group** receives instructions from the optimization module and translates them into actions that adjust the building's energy systems. This could involve dimming lights, adjusting thermostats, battery management for on-site energy storage, or controlling charging of electric vehicles. The **abnormal operation detection group** monitors sensor data and compares it with expected values based on historical data and current forecasts. This allows the system to identify deviations from normal operation.
- **External Grid Network Management module**: This module manages the external grid network's interactions with the iGFBs.

The **Middleware layer serves** as the core data management infrastructure for the iGFB Data Space. This centralized layer orchestrates collaboration among participants and can be further decomposed into two sub-layers focused on distinct functionalities: **trust and sovereignty management**, and **interoperability management**.

  - The first sub-layer prioritizes establishing and maintaining **data security and participant autonomy** within the iGFB Data Space. A configuration component ensures the Data Space adheres to pre-defined governance models and participant requirements. An iGFB Identity Management component safeguards the ecosystem by managing participant identities and access control. An App Store functions as a secure repository for authorized applications and services that interact with Data Space resources. For transparency and auditability, a Data Workflow component oversees data flow definition, orchestration, and execution, while a Data Flow Logging component maintains a comprehensive record of all data movements.

- The second sub-layer focuses on promoting **seamless interoperability** between the heterogeneous systems and applications participating in the iGFB Data Space. A vocabulary provider establishes a standardized data language to ensure consistent data representation and interpretation. A Data Management Brokerage component acts as an intermediary, facilitating the discovery, registration, and invocation of data management services within the ecosystem. Furthermore, a Metadata Broker manages the registration, discovery, and retrieval of metadata associated with data resources. Finally, a Context Broker (Event Management) component enables real-time decision-making and automated processes by facilitating the management of contextual information and events within the iGFB Data Space.

The WeForming Middleware surpasses a static architecture by functioning as a dynamic platform that facilitates continuous modular updates and enhancements. This is evident in the central-left block of the reference architecture, which serves as a foundation upon which essential services for intelligent Grid-Forming Building (iGFB) operation can be constructed. These services encompass a diverse range including:

- Marketplace Services: These encompass functionalities such as billing and digital contract management.
- Compliance Services: This category ensures adherence to regulations, including those mandated by the EU regarding data governance.
- Joint Business Models: This facilitates the creation of collaborative data products leveraging the Middleware's capabilities and context management services.
- Building Analytics Services: By leveraging Middleware metadata (e.g., geolocation, SRI rating, energy consumption profiles), these services provide advanced building analysis functionalities.

This dynamic and extensible nature of the WeForming Middleware fosters a constantly evolving ecosystem that adapts to meet the emerging needs of iGFB participants.

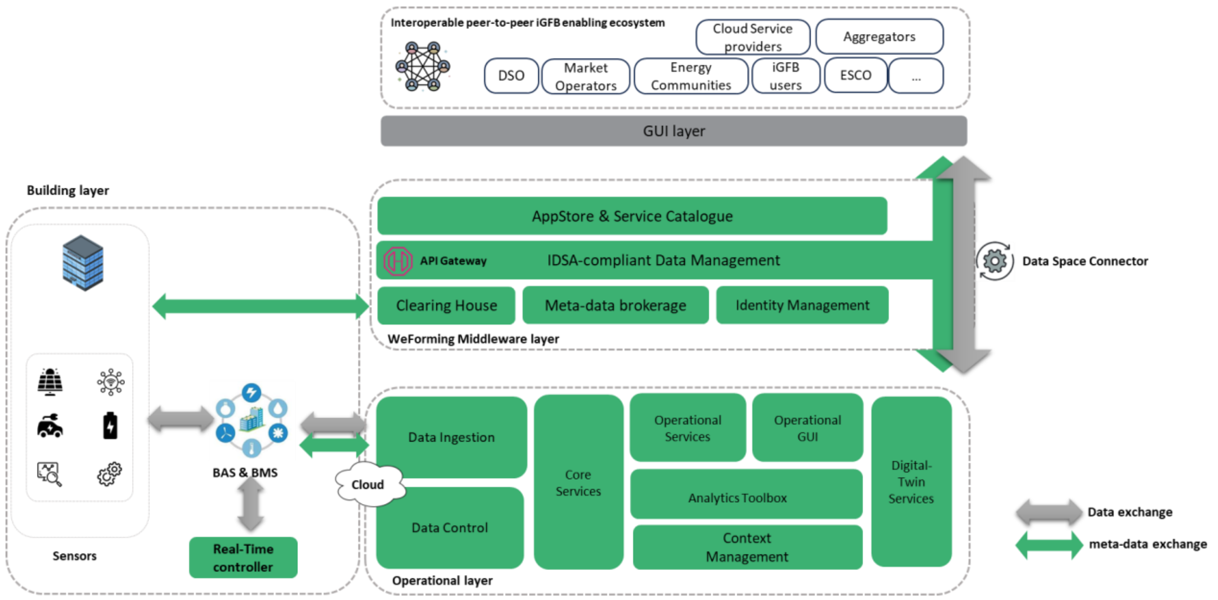

FIGURE 58 WEFORMING IGFB REFERENCE ARCHITECTURE (DATA FLOW VIEW)

5.4.3. Logical definition of WeForming RA hierarchical structure

4.4.3.1 WeForming functional requirements collection process

During a two-day in-person meeting held on February 5th and 6th, 2024, in Karlsruhe, Germany, as part of the WeForming Demo coordination meeting, participants gathered to begin the process of deriving the functional requirements arising from their Demos. The meeting brought together approximately 20 attendees, including representatives from the WeForming demo sites across Europe, the leader of Work Package 2 ("WeForming Stakeholders Requirements and System Specifications"), and the leader of Task 2.7 ("WeForming Operational Framework design – Building Interoperable Reference Architecture for optimised building-to-grid integration"). The primary objectives of the meeting were to:

- Enhance project partner understanding of the project goals.
- Explore the potential applications and challenges faced by each demo site.
- Establish a robust foundation for the measurement and evaluation plan.
- Equip all participants with the necessary knowledge to systematically and consistently derive business use cases and data exchange needs based on the demo site needs.

A targeted training session took place to develop a common consensus among all partners with regards to functional requirements. The training session covered the well-established Smart Grid Architecture Model and IEC 62559-2 processes for defining use cases and deriving functional requirements. Recognizing the varied backgrounds, technical expertise, and experience of the demo leaders with these processes, the Task 2.7 leader developed a custom designed form and approach for collecting the functional requirements.

The form is shown in Figure 59. This form consists of three key sections, guiding demo leaders through a structured approach. The first section focuses on naming the use case arising from their specific demo, along with documenting its overall scope and objectives. Moving on, the second section delves into the use case profile. Here, participants identify the business actors involved, outlining their roles and types. The section then guides users through describing the business-level interactions occurring between these actors, step-by-step. Finally, the third section addresses the information exchanged during these interactions, ensuring all necessary data points are captured. Additionally, this section caters to listing any essential conditions that may be relevant to the use case.

The session fostered an interactive environment where participants co-created a representative example. This example stemmed from a pool of use cases previously derived throughout the two-day meeting. A collective voting process ensured the chosen example best reflected the overall project/demos goals. Following the selection, a dedicated Q&A session addressed any lingering uncertainties faced by the WeForming Demo partners. With the example as a foundation, participants collectively analysed its details, explored its application within their individual demos, and engaged in a brainstorming exercise. This brainstorming focused on systematically modifying specific steps within the example to generate similar use cases and corresponding functional requirements.

This tailored format ensured the training effectively addressed the specific needs and skillsets of the WeForming Demo leaders, and that it would be practical and useful to them for collecting the functional requirements. The whole process set a new practice for collaboration and innovation within the energy sector.

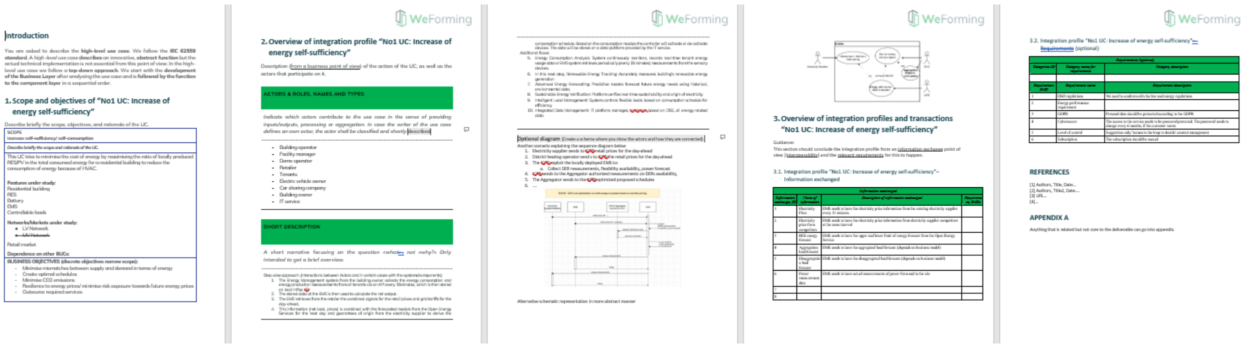

FIGURE 59 TEMPLATE FORM FOR DERIVING THE HIGH-LEVEL USE CASES

5.5. Key Findings from the Initial Reference Architecture Development and Next Steps

Key Findings

- Both literature and on the BUCs have identified the diversified (energy) needs of the building sector (e.g., across shopping mall, touristic buildings, energy communities etc); however, the common denominator is the need for exchanging data with a broader interoperable ecosystem.
- High-level system specifications for some demonstrators due to early phase
- Training sessions facilitated co-creation and establishing common ground

Next Steps

- Validate use cases against best practices (SotA) for consistency
- Standardize terminology and phrasing across Business Use Cases (BUCs) and functional requirements to facilitate grouping and enhance interoperability
- Work along the development of System Use Cases that will provide clarity on systems' requirements
- Ensure alignment of use cases with existing or planned data models/ontologies within the iGFB domain
- Conduct further analysis and refinement of user-centred requirements and functional specifications.
- Integrate feedback from the development of the technological enablers and Middleware to refine existing use cases (or create new ones) and adjust corresponding functional requirements.
- Refine the W-IBRA towards devising reference components for the digitalization of the building sector.

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APPENDIX A

Survey on the assessment the buildings' end-users, and occupants' engagement and awareness T2.4

Introduction

As an introduction to the survey, we propose two definitions so the participants will understand the topic.

This survey is part of an EU funded project and it has a purpose to measure your views on smart buildings. To avoid wrong interpretations, this is a short dictionary of definitions used in the survey.

Building design, construction and use evolve according to the needs of society and adapt to new technologies. Additionally, the need to respond to the climate crisis is more evident than ever, requiring a rapid and large-scale increase in the use of renewable energy sources in buildings and a reduction of their energy consumption.

Intelligent Grid-Forming Buildings (iGFBs) integrate smart technologies that transform buildings from passive consumers of energy into active nodes of the energy network. IGFBs integrate various forms of energy, manage electricity loads, and optimize energy use within individual structures or across premises, increasing the flexibility of electricity grids, district heating, and other networks.

A smart grid is a network that intelligently integrates new digital information technologies that enable two-way communication between energy consumers, utilities, and energy producers. Moreover, it enables interaction between the building's energy systems and the wider electricity grid. Finally, through advanced metering infrastructure, a smart grid can increase energy efficiency and improve the control of users over their energy consumption.

More information about the project: https://weforming.eu/

This survey is conducted by HOLISTIC in the context of the project WeForming, funded by the Horizon Europe programme of the European Commission. Your participation is voluntary. All your data will be analysed anonymously, treated in accordance with the European Union's data protection regulations (GDPR) and used for scientific purposes only. Your data cannot be linked to you as an individual and will not be passed on to third parties. You can withdraw consent by contacting us at dpo@holisticsa.gr.

-Agree

Demographics

- **Age**

18-24

25-34

35-44

45-54

55-64

65+

Gender

Female

Male

Non-binary

Rather not to say

-**Education**

High School

Bachelor's degree

Master's degree

PhD

Post PhD

-**Occupation**

Administrator

Engineer

Researcher

Private employee

State employee

Student

Unemployed

Retired

We're currently implementing real-life demonstrations of WeForming in six cities**, and we're interested in gathering feedback from end-users regarding its benefits and potential improvements. Are you located or employed near any of these cities?**

Rout Lens, Luxembourg

Viseau, Portugal

Krk, Croatia

Martelange, Belgium

Fornes-Granada, Spain

Karlsruhe, Germany

Other

If none of the above applies to you, please write your answer here:

Smart Grids

Where have you heard from about smart grids?

1. Social media
2. European union media outlets
3. State/Community media outlets
4. Workplace
5. Family or friends
6. From this survey
7. Other (...)

Are you aware of the concept intelligent Grid-Forming Buildings (IGFBs), which use advanced technologies to optimize energy use and interact with the electricity grid?

1. Yes
2. To some extent
3. No

Please explain what the concept of intelligent Grid-Forming Buildings (IGFBs) is or what it should be:

(Open-ended question)

Select to what extent you agree or disagree with the following statements about the properties of smart grids:

(5-Point scale: Strongly agree to Strongly disagree)

Statements

- Intelligent Grid-Forming Buildings (IGFBs) can contribute to energy efficiency, cost savings, and sustainability compared to traditional buildings

-Smart grids differ from conventional grids in terms of self-healing capacity, resilience to natural disasters and improved power quality

-Conventional grids cannot distribute energy from multiple renewable energy sources

-Smart grids allow consumers to monitor and control their energy usage in real-time

-Smart grids facilitate two-way communication between utility companies and end-users for efficient energy management

-Smart grids utilize sensors and communication technologies to monitor and manage electricity flow in real-time

Select to what extent you agree or disagree with the following statements:

(5-Point scale: Strongly agree to Strongly disagree)

Statements

-The use of smart meters in grids provide more accurate measurement and billing of electricity consumption

-Smart grids are vulnerable to cyber attacks, making them less secure than conventional energy systems

-Smart grids are only relevant for those who use renewable energy sources

-Through smart grids the carbon will be lower since renewable energy resources can be used efficiently

- Smart grids contribute to a more resilient power system, reducing the impact of natural disasters, power outages and improving overall community safety

-The implementation of smart grids supports the integration of a higher percentage of renewable energy sources, leading to a greener and more sustainable energy future

-Smart grids help reduce carbon emissions and mitigate the effects of climate change by optimizing energy use and promoting energy efficiency

- Smart grids let you monitor in real-time the electricity rises so you have the opportunity to reduce the energy bills by choosing the volume and price of consumption that best suits you

Monitoring Energy Use

Which of the following methods would help you get more involved in monitoring your energy use?

1. **Education** on methods to reduce energy consumption
2. **App** where you can monitor how much energy you consume any time
3. **Reduction of the energy bill** when you use smart ways to reduce your energy consumption

Statements

Select to what extent you agree or not with the following statements

(5-Point scale: Strongly agree to Strongly disagree)

Statements

-I am aware of the electricity that I consume

-I would reduce my electricity consumption if i knew **how much i consume**

-The idea of having **control** over my energy usage through smart grid technologies is appealing to me

-I would adopt new technologies, such as smart meters, to improve **energy efficiency** in my home OR workplace

-I believe that power grids can enhance the **reliability** of my electricity supply

-I am concerned about the **environmental impact** of energy consumption and I believe smart grids can address it

-Financial incentives, such as reduced electricity bills, would influence my decision to adopt smart grid technologies

-I would participate in demand response programs if there were **financial incentives** or rewards offered for reducing my electricity usage during peak hours

-Adopting smart grid technologies would contribute to achieving greater **energy independence**

Would you be interested in having features of Intelligent Grid-Interactive Efficient Buildings, such as automated energy management and demand response capabilities in your municipality that promote more environmentally friendly practices?

1. Yes
2. To some extent
3. No

Which of the following would drive you to engage in smart grid management programs?

1. Reduced energy bills
2. Independence to control your energy usage
3. Lower environmental impact
4. None of the above
5. Other (...)

Barriers

What would you see as potential barriers to the adoption of smart grids in buildings?

1. Lack of Information
2. Implementation costs
3. Privacy and cyber security
4. Legislation barriers
5. All of the above
6. Other (...)

Which of the following would concern you the most in the use of a smart grid? (Rank them according to your priority, from 1 to 5)

- ❑ Security and Privacy
- ❑ Quality of Electricity
- ❑ Reliability of energy system
- ❑ Change of routine
- ❑ Other (...)

Is this concern due to (Rank them according to your priority, from 1 to 3):

- ❑ Not enough information available to me
- ❑ Not enough understanding about how smart grids work
- ❑ Concerning articles about the inefficiencies of smart grids

Select to what extent you agree or disagree with the following statements about potential barriers of smart grids:

(5-Point scale: Strongly agree to Strongly disagree)

Statements

-I would **trust** an external party to control my electrical appliances (e.g. washing machine, fridge) for more efficient electricity usage and for giving me the ability to monitor at any time my energy consumption

-I would be concerned about my **privacy** when using smart grid technologies and sharing information about my energy usage habits

-It is challenging to understand the **technical aspects** of smart grid technologies and how they impact my energy consumption

-There is a **lack of information (or education)** about smart grid technologies, making it challenging for me to understand how they work and adapt to them

APPENDIX B

In the following we provide the functional requirements gathered from the WeForming participants.

Demo Requirements

Req Code	Function needed	Description (functional)	Primary Architectural component involvement
Demo Belgium			
FRD01a	Interface between EMS and Market Operator/Electricity retailer	The Energy Management system (EMS) collects forecasts of the dynamic electricity prices and grid tariffs for the day-ahead via API	Connector: REST APIs (external Platform Integration)
FRD01b	price forecasting related to dynamics electricity price and grid tariffs	Application for price forecasting related to dynamics electricity price and grid tariffs	AI/ML tools
FRD02a	Interface between EMS and PV forecast provider (Service Provider)	The EMS collects PV forecast via API and compute load forecast	Connector: REST APIs (external Platform Integration)
FRD02b	PV forecaster as part of App Store	PV forecaster as part of App Store	Middleware: App Store
FRD03	EMS to cloud datahub interface for frequent push & pull information	The EMS system collects real-time energy consumption and energy production measurements from all devices MQTT every 2 to 5 seconds, which is then stored in a cloud datahub	Connector: REST APIs (external Platform Integration)
FR04	Sustainable Energy Verification	Platform verifies real-time sustainability and origin of electricity	Middleware: App Store
FR05	Settlement service for the electricity domain	Settlement: System calculates ex-post the real cost of electricity based on validated dynamic prices and grid tariffs	Middleware: App Store

FR06	Interface between EMS and Market Operator balancing needs	The EMS collect in real-time TSO balancing signal	Connector: REST APIs (external Platform Integration)
FR07	Interface between EMS and Market Operator response	The EMS send back to the TSO the response to the balancing signal	Connector: REST APIs (external Platform Integration)
Demo Portugal			
FR08	Interface between EMS, HVAC and Thermal Energy Storage (TES) system	The EMS shall collect data on HVAC parameters and on the Thermal Energy Storage (TES) System, including the current state, capacity and availability.	Connector: REST APIs (external Platform Integration)
FR09	Forecast tool for thermal energy demand	Forecast tool to predict the thermal energy demand for the upcoming multi-periods based on historical building operation data (i.e., occupancy and ambiental), with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	AI/ML tools
FR10	Interface between EMS, grid/market operators, and retailers	The EMS shall collect information from the energy market, grid operators and retailers to optimise energy costs, carbon footprint and grid contributions. This includes for example Time of Use energy tarrifs, balancing market prices, and RES penetration in the grid energy mix.	Connector: REST APIs (external Platform Integration)
FR11	Interface between EMS and environmental variables	The EMS shall collect data on environmental variables impacting the building energy demand, such as external temperature and weather conditions.	Connector: REST APIs (external Platform Integration)
FR12	Forecast tool for PV production	Forecast tool to predict the energy production from on-site PV plant, with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	AI/ML tools
FR13	Interface between EMS and DER plants	The EMS shall collect data on the energy production of Distributed Energy Resources (DER) connected to the building.	Connector: REST APIs (external Platform Integration)

FR14	Forecast tool for building energy consumption	Forecast tool to predict the aggregated energy consumption of the building, with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	AI/ML tools
FR15	Documenting renewable energy certificate (guaranty of origin)	*(Building owner- Retailer)*Documentation of renewable energy generation for regulatory and sustainability reporting.	
FR16	Forecast tool for available flexibility	Forecast tool to predict the aggregated upwards and downwards flexibility available for participating in balancing markets, with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	AI/ML tools
FR17	Interface between EMS and Building Operator	Interface through which the Building Operator may input to the EMS set points and constrains on DER, ESS, and controllable loads, collected from Building Users.	Connector: User Interface
Demo Luxembourg			
FRD18	DSO requesting services	The DSO may request a particular service from the demo optimizer for a given volume, price, duration, etc.	Connector: REST APIs (external Platform Integration)
FRD19	DSO evaluating offered service	The DSO may review the resposne to the service request and reject or accept the offer.	Connector: REST APIs (external Platform Integration)
FRD20	Building manager/ occupants paremeterizing demo optimizer	The end users can add constraints to the demo optimizer. Some examples are, BESS charging/discharging power limits. Available time slots for controlling HVAC systems, Ev charging time-slots, etc.	Connector: REST APIs (external Platform Integration)
FRD21	Demo Optimizer results	Once the optimal schedulas are computed they will be avaialble for display in the UI.	Connector: REST APIs (external Platform Integration)
FRD22	Monitoring Assets	The end users can view at any time the measurements of their assets . Edit their operational state (ON/OFF)	Connector: REST APIs (external Platform Integration)

FRD23	Alarm, warning, other notificatrions	Notify by email or SMS end users in caseof an alarm a warning occured. Perhaps send notifications when computed schedules are ready.	
FRD24	Market data	The platform need to receive data about the energy market prices, volumes etc.	Connector: REST APIs (external Platform Integration)
FRD25	Weather data	The platform need to receive data about temperature, irradiation, wind speed etc.	Connector: REST APIs (external Platform Integration)
Demo Croatia			
FR26	DSO data hub connector / connector to electricity consumption data	For almost all use cases the real-time information on energy consumption is needed. Croatian pilot has (within the "inherited" data hub) established a place for this to be gathered, but note that the DSO (and the metering operator) is according to the regulations from 2023, will be establishing an official data hub that will be used for this purpose in the future. This, however, will not happen during WeForming but should be in mind when functional specification is designed.	Connector: REST APIs (external Platform Integration)
FR27	Water consumption data	For the Croatian demo UC1, water consumption participates in seasonal storage modeling. It can be modeled through electricity consumption of water pumps which is available via the 15-minute DSO data.	Connector: REST APIs (external Platform Integration)
FR28	Water reservoir level	Available indirectly for the Demo 3 UC1 from the local utility.	Connector: REST APIs (external Platform Integration)
FR29	Meteorological data	This is required as inputs for the forecasts of Croatian use cases. Both live data from local station and the model provider is available.	Connector: REST APIs (external Platform Integration)
FR30	PV operational data	Live data from diverse sizes of PVs is necessary for the Demo 3 UC2. This will require direct connection to data, API	

		integration, AND data import - all three situations exist already.	
FR31	BRP (DSO or TSO?) data - balancing responsible party interface	Balancing responsible party data required for forecasting of required grid services, and modeling of potential revenue from such services	
FR32	Market data interface	Pricing data gathered from relevant markets to be used in modeling and forecasting	Connector: REST APIs (external Platform Integration)
FR33	User interface to monitor the assets	In order to make the solution attractive to the end users, we should offer them some supervision on the assets and capability of removing the assets from the availability pool.	
FR34	Community-level interface to monitor aggregated data	At the municipal utility level, the aggregated data collected from granular data should also be available (Eg. total excess production and similar)	
FR35	Forecasting tool to evaluate flexibility and redispatchable loads	Based on historical usage patterns and based on meteorological numerical weather forecast, this tool should provide margins for flexibility and eventual redispatchable loads. This is a statistical forecasting task, best solved by an advanced ML technique. It composes the community level forecast based either on aggregation of individual forecasts, or, more likely, based on most important "lighthouse" behaviors, akin to regional nodal injection forecasts of wind power production.	AI/ML tools
FR36	ROI calculation tool	Utilized in performance analyses of the UC3 in Croatian demo: assesses the capex investments required to elevate a buildiing to a particular class of grid-supporting building, and compares that to revenues obtainable by participation in the grid support schemes. Estimation of both sides requires an ML-based approach to historical data. Three steps are needed: Classification of building, extraction of suitable data (if not available for the exact	AI/ML tools

		building), and estimation of possible income, and finally ROI calculation.	
FR37	Community-level aggregation tool	This tool takes the individual forecasts and extracts the aggregated data at community level. It is a companion to the above mentioned forecast tool. It is a separate functional requirement so it can be used also for monitoring (and not only within forecasting). This FR may need to be decomposed into availability of resources aggregation vs. consumption aggregation - may need two separate types of ML algorithms here.	AI/ML tools
FR38	Building performance modeling tool	An integration with existing tool (such as DesignBuilder) or a simplified model for building envelope performance is required to model the prospective building performance once upgrades of the building envelope or the smart readiness upgrades are achieved. For the current as-is situation there may be data, but for the post-investment situation, a model-based evaluation is needed as an input to ROI calculator.	AI/ML tools
FR39	In-house device actuator: Interface between the assets and the RT controller	The whole value chain of the in-house device activation must work, and this includes setting setpoints to PV inverters. This is a requirement for any active response of the buildings. For this demo this means Modbus (specific for the inverter types installed) and indirect communication to SCADA system via 104 protocol for larger PV plants.	RT controller
FR40	Building occupancy predictor	Important on a short-term elsewhere, but even on a seasonal level when Croatian pilot is considered. This predictor forecasts whether in a given period a building is going to be occupied and consequently serve as an input to the tools predicting available operational range of the devices. Empty building can export virtually the whole rooftop PV consumption.	AI/ML tools
Demo Spain			

FR41	Connection of Renewable Energy Community with the DSO data exchange platform	Ensure connectivity of the WeForming tools with the DSO data exchange paltfrom	Connector: REST APIs (external Platform Integration)
FR42	Optimization results visualization tool	This tool enables the REC operator to visualize the suggested optimization results and evaluate their impact on the REC.	Connector: User Interface
FR43	Smart Contracts Generation	This requirement satisfies the automatic decomposition of the obligations created by the optimization tool into smart contracts binding the members of the REC among themselves and to the aggregator.	Middleware: Clearing House
Demo Germany			
FR44	measurement of the power at the GCP	The power at the grid connection point has to be measured and communicated	RT controller
FR45	forecast of inflexible loads	The inflexible load has to be forecasted for the next 24 hour horizon	AI/ML tools
FR46	PV forecast	The PV generation has to be forecasted for the next 24 hour horizon	AI/ML tools
FR47	frequency, power and SoC measurements of battery	frequency, power and SoC have to be measured in a 1 second-resolution	RT controller
FR48	DSO interface	a power limitation signal from the DSO is to be received through smart-meter infrastructure	Connector: REST APIs (external Platform Integration)
FR48	market prices	day ahead spot market prices should be received daily	Connector: REST APIs (external Platform Integration)
FR49	battery, EV and heat pump optimization	optimized schedules for flexible loads must be calculated by a scheduler	AI/ML tools
FR50	FCR communication	the possibility to provide FCR has to be communicated to an aggregator	Middleware/connector: Data access policies

Technological Enablers Requirements

Req Code	Function needed	Description (functional)	Primary Architectural component involvement
Digital Platforms			
FRDP01	Access to the SOC of the BESS	Allow us to know the charge level of the BESS	Power Processing Hub
FRDP02	Access to the market prices	Allow to assess it the market is in favor of a us charging the BESS or discharging it	Middleware: Context Management/Broker*
FRDP03	Connect to CRCL plateform	Allow the BESS to connect and send data to CRCL plateform to exchange data	Power Processing Hub
FRDP04	Data exchange between WeForming plateform and CRCL platefrom	Prediction of lifetime, operating conditions, and data analysis for CRCL ML models	AI/ML tools
FRDP05	Access to Grid operators info	Allow the system to predict using ML models and prepare to charge or discharge the battery	AI/ML tools
FRDP06	HMI and remote access	Allow an abilitated entity to have access to the HMI/controls of the BESS as well as all the informations	AI/ML tools
FRDP07	Interconnection iGFB and distribution grids	Measure grid parameters at secondary substations where iGFB are connected to	RTU interfaces
FRDP08	Communication between RTU and real-time controller	Communication by using standardized communication protocols, like Modbus or IEC104 with real-time controller (T3.2)	RTU interfaces
FRDP09	User access to real-time usage of owned assets	The end users should be able to view the assets performance in real-time (we can agree later on the exact resolution)	Digital operational platforms (T3.1)

FRDP10	User access to computed schedules of controllable assets	The end user should be able to view the computed schedules	Digital operational platforms (T3.1)
FRDP11	User ability to set asset operational parameters	The end user should be able to set operational parameters of owned assets, like preffered temperature settings etc.	Digital operational platforms (T3.1)
FRDP12	Platform ability to receive data from Energy Markets, or Weather Stations	The platform should be ablet to receive data from Energy Markets or Weather data to be able to make forecasts.	Middleware: App Store
RT Controller			
FRRT01	Receive power target set points	Receive a timeseries of set points that the building should follow (at grid connection or other defined point)	RT controller
FRRT02	Get live state of all power flows in the building	Get meter values of grid exchange, local production (PV, ...) and the current state of the flexible devices	RT controller
FRRT03	Cyclically calculate deviation of live state from set points	Add or subtract all defined data points (live values and set point) to get real time deviation	RT controller
FRRT04	Send live updates to flexible devices	Change the power consumption of feed in according to the calculated deviation	RT controller
FRRT05	Implement a fall-back option	Defined operation mode, if no new set points are received (for example just do self consumption)	RT controller
FRRT06	Store target set points	Have some permanent storage for the target set points that remains persistent even in the	RT controller

		event of a power failure or restart	
FRRT07	Monitoring and debugging	Have an interface to contact the RT controller and see its state	RT controller
Digital Twins			
FRPH01	Description of the functional typology of the buildings	Type of building based on its primary usage and occupants activities	Connector: User Interface
FRPH02	Identification of assests and systems	Identification of all technological assets	Connector: User Interface
FRPH03	Inputs of technical parameters of the assets	Technical specifications and configuration of assets according to the data models defined for the simulations (nominal power, efficiency, etc...)	Connector: User Interface
FRPH04	Economical parametrization of assets	Economic parameters relative to each asset for the technical-economic simulation: initial investment, O&M costs, replacement cost, lifetime, derating factor, ...)	Connector: User Interface
FRPH05	Renewable resources time series	TMY or remote-sensing data driven models of temperature, solar irradiance, wind speed.	Connector: REST APIs (external Platform Integration)
FRPH08	Description of occupant's activity dynamics	The charactherization of the building usage is tranlated in energy demand profiles using standardized methods for generating synthetic energy demand profiles (occupancy density, typical daily, monthly and yearly profiles frequency)	Connector: User Interface

FRPH09	Parametrization of users' requirements	User imposed constaints for optimization such as thermal comfort setpoins, ventilation requirements, minimum operating hours of appliances or other machineray	Connector: User Interface
FRPH10	Access to the use case local Energy tariffs	Local retailler energy tariffs of eletricity and other final energy consumed in the use case (heat, gas, hydrogen, etc..)	Connector: REST APIs (external Platform Integration)
FRPH11	Access to markets' prices	Historical and day ahead prices data (energy, imbalances market)	Connector: REST APIs (external Platform Integration)
AI/ML applications			
FRML01	ID of the consumer	the Smart meter ID of the consumers	Network traffic monitoring tools
FRML02	Historial Timeseries of Demand	The one year historical smart meter data of the consumers for training	
FRML03	Weather	Temperature, Solar Irradiation, Wind Speed	
FRML04	PV genration	Historical PV generation data	
FRML05	Wind generation	Historical Wind generation data	
FRML06	Market Price	Historical market price data	
FRML07	Location	geographical coordinates (longitude and latitude)	

Technological Digital Interoperability Requirements

Req Code	Function needed	Description (functional)	Primary Architectural component involvement
IDS Data Process			
1. ONBOARDING			
1a.Aquire identity			

FRIDS01a	Acquire identity for new WeForming participant	Interested party willing to become IDS member makes request form Evaluation Facility	Middleware: Identity Management	IDS RAM	
FRIDS01b	Acquiry of evaluation for a Service Provider's component	Service provider requests the evaluation of new service component from the Evaluation Facility	Middleware: Identity Management/CA	IDS RAM	
FRIDS02	Certification Body notifies certication authority for successful certification	Validity certificates are provided to certification authority	Middleware: Identity Management/CA	IDS RAM	
FRIDS03	Generating IDS-ID	The Certification Authority generates a unique IDS ID	Middleware: Identity Management/CA	IDS RAM	
FRIDS04	Provisioning of Digital certificate	The Certification Authority issues a digital cerificate (X.509) to the participant and notifies the DAPS	Middleware: Identity Management/CA	IDS RAM	
FRIDS05	Register of component at DAPS	Digital certificate is deployed at the side of the component(connector) and the component registers at DAPS	Middleware: Identity Management/CA	IDS RAM	
FRIDS06	DTM Interaction	Dynamic Trust Monitoring (DTM) implements a monitoring function for every IDS Component. The DTM shares information with the DAPS to notify each of the two participant in a data exchange transaction of the current level of trustworthiness of the other participant.	Middleware: Identity Management/CA	IDS RAM	
1b. Connector Configuration and Provisioning					
FRIDS06	Define connector configuration model-General information	Service provider to define general information including connector type, version, timestamp of last change made to the configuration, configuation, name of contact person	Connector: Configuration	IDS RAM	
FRIDS07	Define connector configuration model-Lifecycle- Data Flow	Service provider to define the configuration of tasks and connections established by the Data Router between the Data Services and the	Connector: Configuration	IDS RAM	

		Data Bus (i.e., Networking: ports/IPs, for internal and external connections, Security: SSL certificates or publics keys, Compliance/Data Sovereignty: rules before connector deployment (preventing inccorect configuration)			
FRIDS08	Define connector configuration model- Service Configuration	Service provider to define how configuation parameters for Data services or other conector components have to be set, i.e., metadata describing datatypes for input/output among different component.	Connector: Configuration	IDS RAM	
FRIDS09	Define connector configuration model- Publishing : Identity Management	Proper identity management interface closely to integrated with the connector defining the Identity Provider	Middleware: Identity Management	IDS RAM	Connector: User Interface
FRIDS10	Define connector configuration model- Publishing : Accounting	Connector interface to define information for a data exchange transaction between participants, it is necessary to record additional information, such as contract specifications, pricing models, or billing details.	Connector: UC Data App	IDS RAM	Connector: Clearing House
FRIDS11	Define connector configuration model- Publishing : Clearing	Connector to provide interface to describe which Clearing House should be informed regarding a certain data exchange transaction	Middleware: Clearing House	IDS RAM	
FRIDS12	Define connector configuration model	Connector communicates configuration to broker and/ or clearing house	Middleware: Clearing House	IDS RAM	
1c. Security Setup					
FRIDS13	Issue certificate for IDS participant	Connector interface to enable secure communication contacts Certification Authority to	Security, Privacy and Data Sovereignty	IDS RAM	

		issue certificate to the Data Provider or Data Consumer.			
FRIDS14	Connector deploys locally IDS certificate	Connector deploys locally IDS' participant certificate and identification of IDS and self-description as received from DAPS	Middleware: Identity Management/CA	IDS RAM	
FRIDS15	IDS Consumer/Provider configures data access restrictions	Connector provide appropriate funtionality for Data Provider or Data Consumer to configure custom access restrictions for bilateral communications; The Data Provider may serve the same data using different representations or pricing options, so the Data Consumer may select a suitable offer from the Data Provider's Connector description.	Middleware: Service Catalogue	IDS RAM	Connector: UC Data App
1d. Availability Setup					
FRIDS16	Connector option to select a set of available Broker services	Connector provider proper interface for Data Provider/Consuemer to select a Broker from a set of available Broker services (i.e., a registry for Connector self-descriptions) to publish the self-description of their Connector	Middleware: Service Catalogue	IDS RAM	Connector: User Interface
FRIDS17	Broker provider functions for searching	Broker provides functions for searching/browsing/querying for and retrieving registered Connector self-descriptions, including data sources, interfaces, security profiles, and current levels of trustworthiness.	Middleware: Service Catalogue	IDS RAM	Middleware: Context Broker
2. EXCHANGE OF DATA					
2a. Find data provider					
FRIDS18	Connector provides proper interface to find data provider	Connector offers functionality to Data Consumer to be able to send	Middleware: Service Catalogue	IDS RAM	Middleware: Context Broker

		a query to a Broker Service Provider upon selection of a suitable Broker (e.g. based on thematic coverage) and determine the query capabilities (e.g. a graphical search interface or a domain-specific query language)			
FRIDS19	Broker communicate to data consumer the queried result	The Broker then returns the query result to the Data Consumer (via Connector), who needs to interpret the result to find out about the different data sources available in the IDS for providing the data specified in the query	Middleware: Service Catalogue	IDS RAM	Middleware: Context Broker
FRIDS20	Connector provide a human readable and technical interpretation of result from Broker	Each query result must provide information about each IDS Connector capable of providing the desired data, so that the Data Consumer can retrieve each Connector's self description to learn more about how to receive the desired dataset from a technical point of view (e.g., endpoint addresses, protocol).	Middleware: Service Catalogue	IDS RAM	Middleware: Context Broker
FRIDS21	Data consumer direct contact with data provider	Data Consumer may already know a suitable Data Provider. In this case, the Data Consumer can contact the Data Provider directly (i.e. without invoking a broker).	Middleware: Service Catalogue	IDS RAM	Connector: User Interface
2b. Invoke data operation					
FRIDS22	Data consumer -via connector- retrieve usage policies from data provider	Data consumer -via connector- retrieve usage policies based on data provider's self description	Connector: User Interface	IDS RAM	
FRIDS23	Data consumer negotiate policy with data provider	Data consumer to be able to negotiate with data proviers sending counter offers for data usage policy	Connector: User Interface	IDS RAM	

FRIDS24	IDS participants reach aggreement on policy	Accept policies to be deployed in both sides and send in policy persistence	Connector: User Interface	IDS RAM	
FRIDS25	Policies locally deployed at IDS , iforming policy persistence	Negotiated polices are deployed at connectors' level	Connector: User Interface	IDS RAM	
FRIDS26	Data consumer conducts data operation call		Connector: UC Data App	IDS RAM	
FRIDS27	Notification of data operation call at clearing House	Upon data consumer request for data a notificiation is sent at clearing house for logging data operation request	Connector: Clearing House	IDS RAM	
FRIDS28	Notification of data operation call reception at clearing House	Upon data providers reception of data consumer's request a notificiation is sent at clearing house for logging reception	Connector: Clearing House	IDS RAM	
FRIDS29	Clearing house logs in a persisternce database all transactions	Clearing house logs in a persisternce database all transactions ensuring data provenance tracking infrastructure	Middleware: Clearing House	IDS RAM	
FRIDS30	Notification of data operation result sent at clearing House	Notification of data operation result sent at clearing House from data provider	Connector: Clearing House	IDS RAM	
FRIDS31	Notification of data operation result received at clearing House	Notification of data operation result received at clearing House	Connector: Clearing House	IDS RAM	
3. PUBLISHING AND USING DATA APPS					
3a. Data App Certification					
FRIDS32	App Provider assesses request for a data App	App Provider assesses request for a data App	Middleware: App Store	IDS RAM	
FRIDS33	App Provider sends certification request result to Certification Body	App Provider sends certification request result to Certification Body	Middleware: App Store	IDS RAM	
FRIDS34	Certification Body performs certification process	Certification Body performs certification process for Data App	Middleware: App Store	IDS RAM	
FRIDS35	Certifiation body issues certificate	Certification body issues certificate for Data App	Middleware: App Store	IDS RAM	
FRIDS36	App provider receives certifcate for data App	App provider receives and deploys certificate for data App	Middleware: App Store	IDS RAM	
FRIDS36	App provider publishes data App ata App Store -Provider-	Data App that was successfully certified, the corresponding metadata is stored in the	Middleware: App Store	IDS RAM	

		App Store for being retrieved by users (e.g., Data Consumers or Data Providers) via a search interface			
3b. Use Data App					
FRIDS40	App User UI to search for available Data Apps	App User UI to search for available Data Apps	Middleware: App Store	IDS RAM	
FRIDS41	App User selects Data App compatible format	App User selects Data App compatible format being compatible with user's connector specifications packaging format	Middleware: App Store	IDS RAM	
FRIDS42	IDS user retrieves Data App	IDS user retrieves Data App (same as 2b. process)	Middleware: App Store	IDS RAM	

Req Code	Function needed	Description (functional)	Primary Architectural component involvement
App Store & Service Catalogue			
FRCA01	Expose available data capabilities	For the store to offer services, user should expose what they have	Connector: User Interface
FRCA02	Allow/revoke usage of data	Allow the end user to control access to their own data	Security, Privacy and Data Sovereignty
FRCA03	Expose available activation capabilities	Expose active components and active capabilities	
FRCA04	Match apps with the user capabilities	Only expose apps to users where users have required capabilities and services and have accepted the necessary conditions	Middleware: App Store
FRCA05	Match services with the user capabilities	Map the services to users that can use them	Middleware: Service Catalogue
FRCA06	Suggest additional services and apps	Match the current subset of services and apps activated by the user with additional capabilities	AI/ML tools
FRCA07	Connect to external providers of data using delegated credentials	Allow the user to delegate the access to market data and metering data from other providers on users behalf	Connector: REST APIs (external Platform Integration)
FRCA08	Security requirements for user login		

FRCA09	Publish temporary revocation of the service usage	Allow the services to be interrupted (e.g. due to planned system outage)	Middleware: Service Catalogue
FRCA10	A user must be able to interact with the service over a web API provided by the service.		Middleware: Service Catalogue
FRCA11	A user must be able to request a forecast or optimized schedule utilizing the API of the service.		Middleware: Service Catalogue
FRCA12	A service provider must be able to specify the format of the input and output data exchanged due to a user request for a forecast or optimized schedule from the service API.		Middleware: Service Catalogue
FRCA13	A user must be able to fit user specific parameters of a service utilizing its API.		Middleware: Service Catalogue
FRCA14	A service provider must be able to specify the format of the input and output data exchanged while a user interacts with the API of a service to fit the user specific parameters.		Middleware: Service Catalogue
FRCA15	A user must be able to store fitted user specific parameters locally.		Middleware: Service Catalogue
FRCA16	A user must be able to make calls to the API of the service which take several hours to compute		Middleware: Service Catalogue

Req Code	Function needed	Description (functional)	Primary Architectural component involvement
Connector FRs			
FRC01	Network Traffic Monitoring Tools	Implement tools to monitor, analyze, and manage the flow of data across the network, including performance management, anomaly detection, and security.	Middleware: Context Management/Broker*
FRC02	Secure Data Transmission Protocols	Utilize secure communication protocols	Security, Privacy and Data Sovereignty

		(HTTPS, MQTT over TLS/SSL, WebSocket) to encrypt and protect data transmissions between network nodes.	
FRC03	Metadata Management	Manage and structure metadata to support data routing, error handling, access control, and data privacy across the network.	Middleware: Context Management/Broker*
FRC04	Real-Time Data Exchange	Facilitate real-time data exchanges using WebSocket for continuous data flow between clients and servers, crucial for system responsiveness and immediate operational decisions.	Connector: REST APIs (external Platform Integration)
FRC05	Edge Device Integration	Ensure the connector is capable of integrating and managing data from edge devices, supporting low-latency operations close to data sources.	Middleware: App Store
FRC06	Cloud and Physical Deployment Compatibility	Define and implement deployment strategies that ensure compatibility and security across both cloud and physical infrastructures.	Connector: Configuration
Security Privacy			
FRSP1	Data Encryption	Implement encryption at rest and in transit to protect sensitive data across all system interactions and storage solutions.	Security, Privacy and Data Sovereignty
FRSP2	Fine-Grained Access Control	Deploy access control mechanisms that allow for detailed permissions and roles to be defined and enforced at every level of system interaction.	Middleware: Identity Management/CA
FRSP3	Anonymization Techniques	Implement data anonymization processes to ensure that personal and sensitive information is obscured, supporting privacy compliance.	Middleware: Administrative features
FRSP4	Decentralized Security Management	Adopt decentralized approaches to security, allowing for robust resilience and redundancy against attacks, ensuring data integrity and availability across multiple nodes.	Digital operational platforms (T3.1)
FRSP5	Authentication Mechanisms	Develop and integrate robust authentication systems that support multifactor authentication (MFA) to verify user identities and prevent unauthorized access.	Middleware: Identity Management/CA

FRSP6	Authorization Protocols	mplement authorization protocols that ensure only authorized users can access certain data or system functionalities based on predefined policies.	Middleware/connector: Data access policies
FRSP7	Auditing and Compliance Reporting	Create systems for auditing user actions and system changes, providing detailed logs that are essential for compliance reporting and forensic analysis.	Middleware: Administrative features
FRSP8	Policy-Based Security Management	Develop policy-driven security management systems that automate responses to security events and ensure compliance with organizational and regulatory standards.	Middleware: Administrative features

APPENDIX C

In the following we provide the Business Use Cases that were developed by the WeForming Demo partners.

DEMO 1 - Business Use Case 1

SCOPE Optimization of the local use RES and reduce peak demand from electric grid.
Describe briefly the scope and rationale of the UC.
This UC focus the optimization of electric thermal (heat and cold) energy usage and management across multiple buildings within the district. It will be demonstrated an advanced energy management system to optimally control the operation of various energy assets in the RoutLëns district to meet its energy demands efficiently at the lower cost possible. Management concepts as load shifting, peak-shaving and flexible demand modulation will be applied to the multi-energy system resorting to a high-density processing hub, utility scale grid forming hybrid energy storage system (Li-ion BESS and hydrogen storage and fuel cell), among other flexible loads as a large fleet of EV charges. An interoperable cloud-based digital platform (COFIGFB) will allow optimizing the operation of the multi-energy assets of the demonstrator's buildings to meet the objectives selected by users, district manager, and different operators according to their preferences and interests. **Features under study:** **Cloud-based digital operational framework for iGFBs.** **Multi-port power bridge.** **RES (photovoltaic roof-mounted installations and BIPV).** **Grid-forming Hybrid Storage energy system (Utility-scale Li-ion BESS, Second-life Li-ion utility-scale BESS and hydrogen storage combined with AFC fuel cell).** **EV charging infrastructure.** **Geothermal district thermal network supported by heat pumps (geothermal and air-water units).** **Networks/Markets under study:** ● **LV Network** **Dependence on other BUCs:** **N/A**
BUSINESS OBJECTIVES (discrete objectives narrow scope): **Develop Energy Intelligence as a Service (EIaaS) by:** **Maximizing self-consumption: Prioritize the consumption of local RES (Photovoltaic and geothermal thermal energy) within the district to minimize energy associated costs.** **Reducing peak demand: mitigate peak electricity demand particularly during peak hours avoiding high demand prices.** **Enhancing energy resilience: Increase the resilience of the district's energy supply by mitigating power disruptions and fluctuations.** **Targeting 100% renewable energy consumption in the RoutLëns district**

ACTORS&ROLES, NAMES AND TYPES

IKO – District manager –is the promoter and developer of the Route Lëns district. After its construction, IKO will remain as district manager, responsible for the operation of all buildings and infrastructure developed.
LIST – Research & Development – Energy Digital Intelligence development, test and implementation.
Circu Li-ion, GenCell ltd, QBots Energy Ltd, Schneider Electric Espana SA – Technology Providers – Demo partners and suppliers of energy storage, measurement and control systems
Callisto SA – District Thermal energy Utility
Sudstroum – Regional DSO and electricity Utility
CREOS – Electricity Utility

SHORT DESCRIPTION

Step wise approach:

1. Energy modelling of the district's assets and building systems.
2. Development and implementation of a cloud-based digital operational framework for iGFBs (COFIGFB) and its integration into the W-IBRA architecture for the optimal operation of the energy assets of the Route Lëns district.
3. Validation of the smart energy efficiency functionalities using a first high-density power hub at the building level.
4. Validate the smart energy efficiency functionalities.
5. Installation and commissioning of a high-density power processing hub at the district level
6. Oversee the implementation process and operation.

DEMO 1 - Business Use Case 2

SCOPE Enabling RoutLëns district to provide congestion management as a service to the DSO.
Describe briefly the scope and rationale of the UC.
This UC focuses on managing the demand response flexibility of both individual buildings and district levels and the system's energy storage capacity in response to the DSO signals for participation in congestion management of the electricity distribution network. **Features under study:** **Cloud-based digital operational framework for iGFBs.** **Multi-port power bridge.** **RES (photovoltaic roof-mounted installations and BIPV).** **Grid-forming Hybrid Storage energy system (Utility-scale Li-ion BESS, Second-life Li-ion utility-scale BESS and hydrogen storage combined with AFC fuel cell).** **EV charging infrastructure.** **Geothermal district thermal network supported by heat pumps (geothermal and air-water units).** **Grid congestion.** **Networks/Markets under study:** • **LV Network** **Dependence on other BUCs:** **BUC01 – "Energy efficiency optimization of the RoutLëns district"**
BUSINESS OBJECTIVES (discrete objectives narrow scope): **Flexibility as a service – FaaS:** • **Distribution network stability enhancement** • **Congestion management provision**

ACTORS&ROLES, NAMES AND TYPES

IKO – District manager –is the promoter and developer of the Route Lëns district. After its construction, IKO will remain as district manager, responsible for the operation of all buildings and infrastructure developed.
LIST – Research & Development – Energy Digital Intelligence development, test and implementation.
Circu Li-ion, GenCell ltd, QBots Energy Ltd, Schneider Electric Espana SA – Technology Providers – Demo partners and suppliers of energy storage, measurement and control systems
Callisto SA – District thermal energy Utility
Sudstroum – Regional DSO
CREOS – Electricity Utility

SHORT DESCRIPTION

Step wise approach:

1. Installation and commissioning of a 1MW high-density power processing hub with grid-forming capabilities
2. Validate the functionalities of managing grid-support services.
3. Validation protocol of the services offered by the power hub in coordination with the DSO and the IKO manager (Route Lëns district manager).

DEMO 1- Business Use Case 3

SCOPE Optimization of a large EV fleet charging infrastructure integrated in the RoutLëns District .
Describe briefly the scope and rationale of the UC.
This UC, focuses on the energy cost minimization of a large EV fleet charging infrastructure integrated in the RoutLëns District by maximizing the use of the district's flexibility and maximizing self-consumption from local RES. It considers technical and operational constraints, as the maximum power limits imposed by grid connection and operation, as well as other user-driven constraints deriving from EV owners' charging preferences. In this scope optimized adaptative charging algorithms will control the EV charging demand-based ML techniques trained with realistic datasets and will be further refined during the validation based on real data collected from the RoutLëns district. **Features under study:** **Cloud-based digital operational framework for iGFBs.** **Multi-port power bridge.** **RES (photovoltaic roof-mounted installations and BIPV).** **Grid-forming Hybrid Storage energy system (Utility-scale Li-ion BESS, Second-life Li-ion utility-scale BESS and hydrogen storage combined with AFC fuel cell).** **EV charging infrastructure.** **Geothermal district thermal network supported by heat pumps (geothermal and air-water units).** **Networks/Markets under study:** • **LV Network** **Dependence on other BUCs:** **BUC02 – "Congestion Management provision to the DSO"** **BUC01 – "Energy efficiency optimization of the RoutLëns district"**
BUSINESS OBJECTIVES (discrete objectives narrow scope): **Develop "Electric Vehicle Fleet Charging as a Service" (EVFCaaS) base in energy cost reduction, by:** - **Optimizing the demand side flexibility of the EVs charging infrastructure usage.** - **Optimizing the supply side flexibility, using power reserves to limit peak consumption from the grid.**

ACTORS&ROLES, NAMES AND TYPES

- IKO – District manager –is the promoter and developer of the Route Lëns district. After its construction, IKO will remain as district manager, responsible for the operation of all buildings and infrastructure developed.
- LIST – Research & Development – Energy Digital Intelligence development, test and implementation.
- Circu Li-ion, GenCell ltd, QBots Energy Ltd, Schneider Electric Espana SA – Technology Providers – Demo partners and suppliers of energy storage, measurement and control systems
- Sudstroum – Regional DSO

- CREOS – Electricity Utility

SHORT DESCRIPTION

Step wise approach:

1. Study the fundamental requirements of EV penetration expected in the RoutLëns district.
2. Energy modelling of the EV charging system.
3. Optimization and development innovative adaptative algorithms for managing scalable EV fleet.
4. Validate the functionalities in real operation in coordination with IKO
5. Oversee the implementation process and operation in coordination with the IKO.

DEMO 2 - Business Use Case 1

SCOPE Thermal Energy Storage Optimization
Describe briefly the scope and rationale of the UC.
This high-level use case describes the implementation of an innovative function focusing on thermal energy storage (TES) solutions to optimise the energy consumption for thermal loads (e.g., heating swimming pools and maintaining the HVAC and ice rink) in commercial buildings (e.g., Palácio do Gelo). **Objectives:** Minimise the energy consumption and costs associated with thermal management. Utilise advanced TES solutions to ensure optimal temperature control, enhancing visitor comfort. Promote consumption from renewable energy sources from the grid energy mix Utilising asset orchestration and data to optimise thermal energy efficiency and comfort **Features under study:** Commercial building (shopping malls i.e., Palácio do Gelo) Thermal Energy Storage systems (Ice storage system) Renewable Energy Sources (RES) – Grid energy mix Local Energy Management System (EMS) Aggregator EMS Controllable heating loads (HVAC, ICE generator) Water pumps Networks/Markets under study: MV Network On-premises Network **Dependence on other BUCs:** Interaction with BUCs focused on renewable energy generation and demand side response.
BUSINESS OBJECTIVES (discrete objectives narrow scope): Enhance energy efficiency in thermal management for reducing cost. Leverage TES to match thermal energy demand with renewable energy supply. Improve the sustainability and environmental footprint of building operations.

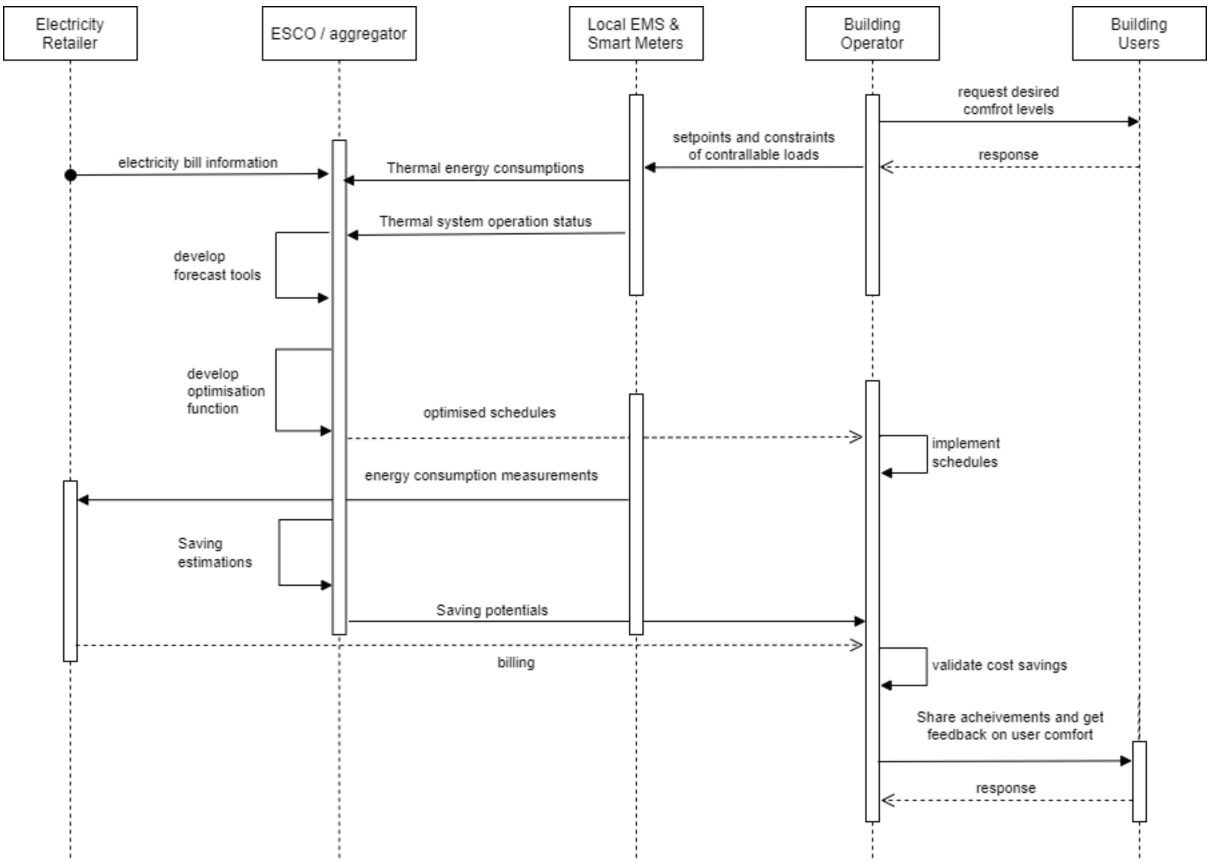
ACTORS & ROLES, NAMES AND TYPES

Tenants and visitors - Benefit from improved environmental conditions.
Building owner – Defines Key Performance Indicators (KPIs) for cost, energy consumed, comfort levels of the building.
Building operator - Oversees energy system integration and operation.
Facility manager (contract manager with commercial users): Manages day-to-day operations of the whole facility related to business and contracts.
Technology providers - Provides hardware or software technology for buildings' energy systems.
Energy Services Company (ESCO) - A party offering energy-related services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself. The ESCO may provide insight services as well as energy management services. [1]
Energy Retailer

SHORT DESCRIPTION

The EMS collects data on thermal energy consumption and production from TES and RES.
Analyses thermal energy demand patterns for the HVAC, ice rink, and swimming pools.
Building operator collects feedback from tenants about their comfort levels
Optimises the charging and discharging of the TES system based on RES availability, thermal demand and comfort constraints.
Implements intelligent load management to ensure cost-and-comfort efficient use of stored thermal energy.
Maintain QOE (quality of experience) of all tenants and visitors of the building.

Diagram



INFORMATION EXCHANGED			
Information exchange, ID	Name of information	Description of information exchanged	*Requirement, R-IDs*

1	HVAC system status	HVAC parameters in the local EMS system.	
2	Thermal energy demand forecast	Aggregator EMS forecasts thermal energy demands for the upcoming multi-periods based on historical building operation data (i.e., occupancy and Ambiental).	
3	RES energy availability	Information on available renewable energy in the grid energy mix for thermal use.	
4	TES system status	Current state, capacity, and availability of the TES system.	
5	Environmental conditions	External temperature and weather conditions impacting thermal energy demand.	

INTEGRATION PROFILE		
Requirements (optional)		
Categories ID	*Category name for requirements*	*Category description*
Requirement R-ID	*Requirement name*	*Requirement description*
1	Regulatory compliance	Operations conform to energy regulations and building standards.
2	Data privacy	Adherence to GDPR for all data handling and processing
3	System security	Secure access to the EMS and protection against unauthorised access.
4	Interoperability	Compatibility of the TES and EMS with existing infrastructure and new technologies.

REFERENCES

[1] ebIX®, EFET and ENTSO-E, The Harmonised Electricity Market Model, 2023

DEMO 2 - Business Use Case 2

SCOPE Enhance the self-consumption of on-site generated renewable energy.
Describe briefly the scope and rationale of the UC.
This high-level use case outlines the strategy for maximising the usage of on-site generated renewable energy by aligning its production with the real-time energy consumption demands of commercial buildings (e.g., Palácio do Gelo). This approach aims to enhance the building's energy self-sufficiency, reduce reliance on the external grid, and promote sustainability. Objectives: Increase the utilisation rate of renewable energy generated from the solar PV plant. Reduce energy wastage and minimise energy import from the grid. Foster a sustainable and eco-friendly energy management system within the building. **Features under study:** Commercial building (e.g., Palácio do Gelo) Solar PV Plant Energy Management System (EMS) Controllable loads (HVAC, lighting, etc.) Networks/Markets under study: MV Network Retail market **Dependence on other BUCs:** This use case interacts with BUCs related to energy efficiency measures, demand response programs, and smart building management systems.
BUSINESS OBJECTIVES (discrete objectives narrow scope): Maximise the direct consumption of solar energy produced on-site. Align energy demand with renewable energy supply to achieve greater sustainability. Reduce operational energy costs and carbon footprint of the building.

ACTORS & ROLES, NAMES AND TYPES
Building owner Building operator - Oversees energy system integration and operation. Solar PV plant operators: Oversee the operation and maintenance of the solar PV installation. Tenants and visitors - Participate in energy-saving initiatives and adapt to consumption schedules.

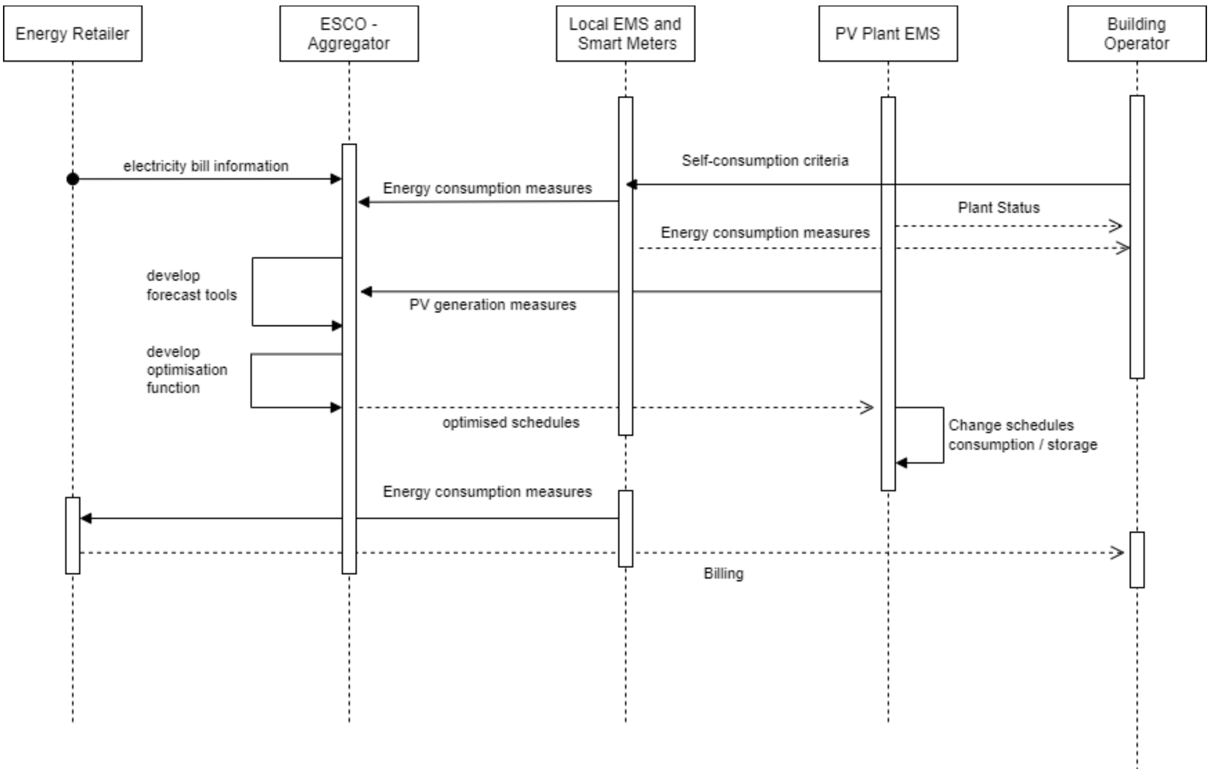
Energy Services Company (ESCO) - A party offering energy-related services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself. The ESCO may provide insight services as well as energy management services. [1]

SHORT DESCRIPTION

The EMS continuously monitors energy production from the solar PV plant and consumption data across the building.
Utilises predictive analytics to forecast short-term energy production and demand.
Adjusts controllable loads dynamically to match with periods of high renewable energy production.
Implements strategies for energy storage or alternative measures during excess production phases.

Diagram

Another scenario explaining the sequence diagram below



INFORMATION EXCHANGED			
Information exchange, ID	**Name of information**	**Description of information exchanged**	**Requirement, R-IDs**
1	Solar energy production data	Real-time and forecasted data on energy generation from the solar PV plant.	

2	Building energy consumption data	Current and predicted energy use within the building	
3	Grid energy prices and demand signals	Information from the energy market and grid operators to optimise energy costs and grid contributions.	
4	Renewable energy certificates (Guaranty of Origin)	Documentation of renewable energy generation for regulatory and sustainability reporting.	

INTEGRATION PROFILE		
Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement R-ID	***Requirement name***	***Requirement description***
1	Regulatory compliance and incentives	Commitment to local and national regulations on renewable energy generation and consumption. Leverage available incentives for renewable energy use.
2	Data protection and privacy	Ensuring the security and confidentiality of energy usage and production data in compliance with GDPR.
3	System interoperability and flexibility	EMS and other systems should be capable of integrating with existing infrastructure and adapting to future technological upgrades.
4	User engagement and participation	Strategies to encourage tenant participation in energy consumption scheduling and efficiency measures.

REFERENCES

[1] ebIX®, EFET and ENTSO-E, The Harmonised Electricity Market Model, 2023

DEMO 2 - Business Use Case 3

SCOPE Trade of flexibility in Balancing Markets (Load frequency control products: mFRR and RR).
Describe briefly the scope and rationale of the UC.
This UC tries to monetize the building's available flexibility, by offering it as load-frequency control products (manual Frequency Restoration Reserve – mFRR, and Replacement Reserve - RR) in the balancing market. The predicted available flexibility (upwards or downwards) for a given Market Time Unit (MTU) is made available for TSO's procurement scheme "market only" (there is no contract or obligation for a grid user to offer the reserve, before the offer), i.e., is bid into the market (as mFRR or RR product). The bid should comply with "bid size", "time-frame", "ramp characteristics" and other requirements. If accepted, activated and executed, the flexibility will be settled billed. **Features under study:** Residential, commercial or industrial buildings RES (if deployed at the moment) Battery (if deployed at the moment) Local EMS Aggregator EMS Controllable loads (e.g., HVAC system, lightning systems; water cooling and heating systems; EV with dynamic charging capabilities) Networks/Markets under study: MV Network Balancing markets Dependence on other BUCs: Interaction with BUCs concerning buildings' energy flexibility.
BUSINESS OBJECTIVES (discrete objectives narrow scope): Explore new revenue streams by using available asset's flexibility. Aggregate asset's flexibility and provide services to TSO. Activate load dispatching actions to meet TSO up or down requests (mFRR and RR markets) Harness the value of distributed flexibility assets to enhance usage of renewables in the energy system and support grid management and balancing needs. Test the performance of EMS (local and aggregator) for demand response management. Maintain QOE (quality of experience) of all tenants and visitors of the building. Minimise CO2 emissions by enabling higher shares of renewable energy generation contribution to the energy mix.

ACTORS & ROLES, NAMES AND TYPES

Building owner

TSO - A party responsible for operating, ensuring the maintenance of and, if necessary, developing the system in a given area and, where applicable, its interconnections with other systems, and for ensuring the long-term ability of the system to meet reasonable demands for the transmission of electricity. [1]

Market operator - party that provides a service of collecting offers to sell and bids to buy electricity, and matching these offers and bids in order to determine a market price at the clearing point. This activity can be conducted in the forward, days-ahead and/or intraday timeframes, and can be combined with transmission capacity allocation in the context of market coupling. This is usually an energy/power exchange or platform. [1]

Energy Services Company (ESCO) - A party offering energy-related services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself. The ESCO may provide insight services as well as energy management services. [1]

Tenants and visitors - to consider the impact of BUC in their comfort.

ROLES:

Building operator – manages the energy system of the building, making use of the EMS and relying on building's assets (from where flexibility will be extracted). (The actor could be the building owner).

BRP - A Balance Responsible Party is responsible for its imbalances, meaning the difference between the energy volume physically injected to or withdrawn from the system and the final nominated energy volume, including any imbalance adjustment within a given imbalance settlement period [1]. (The actor could be the building owner, the ESCO, or a third party).

BSP - Balancing service provider is a party with reserve-providing units or reserve-providing groups able to provide balancing services to one or more LFC Operators. (The actor could be the building owner, the ESCO, or a third party) [1].

LFC (Load-frequency control) Operator - (normally this role is performed by the TSO), responsible for the load frequency control for its LFC Area or LFC Block [1]. (The actor is typically the TSO).

Billing Agent - The party responsible for invoicing a concerned party [1]. (The actor is the Market Operator).

SHORT DESCRIPTION

The Building Operator (BO) gathers information from tenants and visitors (hereinafter Building Users - BU) about desired comfort level and constraints concerning Distributed Energy Resources (DER), Energy Storage Systems (ESS) and controllable loads that may impact them (e.g., hot water produced by solar collectors, thermal storage of swimming pools, Electrical Vehicle Supply Equipment (EVSE), etc.).

The BO identifies new set points and constraints for DERs, ESSs and controllable loads according to the information collected and provides them to the Energy Services Company (ESCO).

The BO collects the disaggregated energy consumption measurements from all BUs and local EMSs and provides them to the ESCO.

The BO collects the disaggregated energy consumption and production measurements from DERs and ESSs and provides them to the ESCO.

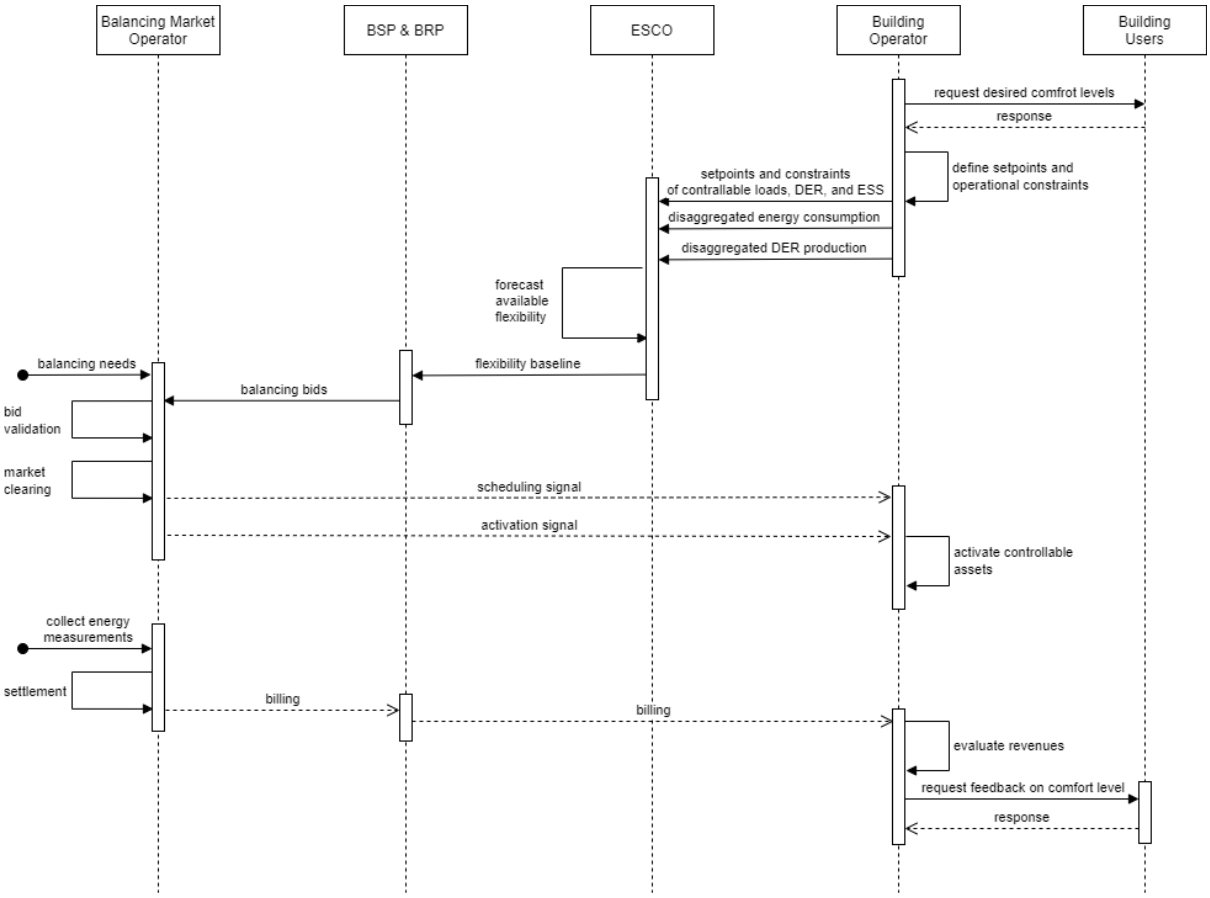
The ESCO develops a forecast tool to predict the aggregated flexibility available in the building, for each Market Time Unit (MTU) of the following day.

The ESCO provides the Balancing Service Provider (BSP) (the two parties may coincide) with the total forecasted flexibility willing to offer to the balancing markets (flexibility baseline).

The BSP offers the available flexibility to the balancing markets through balancing bids.

The Balancing Market Operator (BMO) validates the bids and, according to the system's balancing needs, performs market clearing for each MTU.
If the bid is cleared, the BMO sends a scheduling and activation signal to the BO, to schedule and activate the specific assets providing flexibility.
The BO activates the assets providing flexibility using the EMS.
The BMO collects energy measurements from the grid connection point of the building and performs settlement, identifying market revenues and imbalance fees.
The results of the settlement are sent to the BSP and the Balance Responsible Party (which may be the same entity), which in turn invoice them to the BO.
The BO evaluates the revenues and requests feedback on the comfort levels to the BU, to ensure that the Quality of Experience (QOE) has not been impacted.

Diagram



INFORMATION EXCHANGED			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	Balancing bids	The Balancing Market Operator shall receive from the BSP the balancing bids containing the quantity and price of flexibility offered to the markets, complying with the IEC 62325-351 standard "CIM European market model exchange profile" [2]	

2	Disaggregated load consumption	ESCO needs to have the disaggregated load consumption of the building with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	
3	DER energy production	EMS needs to have the energy production of the DERs with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	
4	ESS energy production / consumption	EMS needs to have the energy production / consumption of the ESSs with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	
5	RES energy forecast	EMS needs to have the range of the probabilistic energy forecast of on-site RES, if any.	
6	Flexibility forecast	EMS needs to have the forecasted aggregated flexibility for the Market Time Units (MTU) of the following day.	
7	Set points and constraints for DER, ESS and controllable loads	BO shall provide the ESCO with set points and constrains on DER, ESS, and controllable loads, collected from Building Users (BU).	

INTEGRATION PROFILE		
Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement R-ID	***Requirement name***	***Requirement description***
1	Regulatory compliance	Operations conform to energy regulations and building standards
2	Data privacy	Adherence to GDPR for all data handling and processing
3	System security	Secure access to the EMS and protection against unauthorized access
4	Interoperability	Compatibility with existing infrastructure and new technologies.
5	Balancing market requirements	Compliance with market requirements for the participation in balancing markets

REFERENCES

[1] ebIX®, EFET and ENTSO-E, The Harmonised Electricity Market Model, 2023
[2] IEC 62325-351: Framework for Energy Market Communications – CIM European Market Model Exchange Profile, 2016

DEMO 2 - Business Use Case 4

SCOPE Minimise costs of energy bills using load shifting.
Describe briefly the scope and rationale of the UC.
The UC aims to leverage flexible loads (e.g., HVAC, thermal storage, etc…) in residential, commercial and industrial buildings with Time-Of-Use (TOU) energy tariffs contracts (static or dynamic), in order to differ consumption from periods with a high energy price (peak hours) to periods with lower prices, i.e., mid- or off-peak hours. Features under study: Residential, commercial or industrial buildings Local EMS Aggregator EMS Controllable loads Energy Storage Systems (ESS), if available Networks/Markets under study: On-premises Network Retail market Dependence on other BUCs: Interaction with BUCs concerning buildings' energy flexibility.
BUSINESS OBJECTIVES (discrete objectives narrow scope): Reduce costs of energy bill Shift consumption from peak hours to mid- and off-peak hours Create optimal set points and schedules for flexible loads Maintain QOE (quality of experience) of all tenants and visitors of the building Resilience to energy prices / minimise risk exposure towards future energy prices Minimise CO2 emissions by flattening the load curve, enabling higher shares of renewable energy generation contribution to the energy mix.

ACTORS & ROLES, NAMES AND TYPES

Building owner

Electricity Retailer

Energy Services Company (ESCO) - A party offering energy-related services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself. The ESCO may provide insight services as well as energy management services. [1]

Tenants and visitors

Technology provider – Provides hardware or software technology for buildings' energy systems.

ROLES:

Building operator – manages the energy system of the building, making use of the EMS and relying on building's assets (from where flexibility will be extracted). (The actor could be the building owner).

SHORT DESCRIPTION

The Building Operator (BO) gathers information from tenants and visitors (hereinafter Building Users - BU) about desired comfort level and constraints concerning potential flexible and controllable loads.

The BO identifies new set points and constraints for flexible assets according to the information collected and provides them to the Energy Services Company (ESCO).

The ESCO collects information of Time-Of-Use (TOU) prices (static or dynamic) from the Electricity Retailer (using the electricity bill).

The BO collects the disaggregated energy consumption measurements from all building users and local EMSs and provides them to the ESCO.

The ESCO inputs set points, constraints, energy consumption measurements to the aggregator EMS.

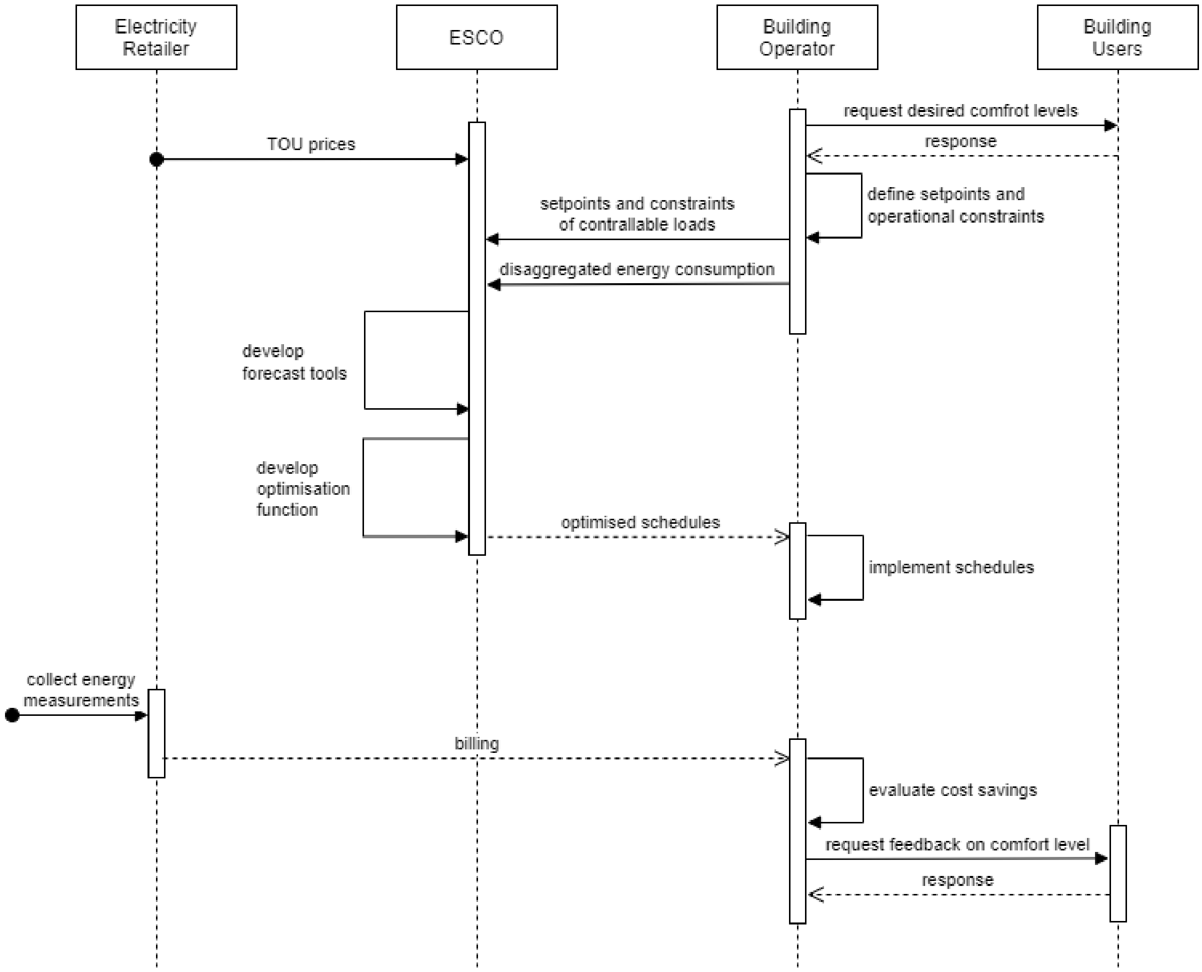
The ESCO develops a forecast tool to predict the dynamic electricity prices, if applicable.

The ESCO develops an optimisation function using metering data, set points of the flexible assets, electricity prices, forecasted dynamic electricity prices (if applicable), with the goal of minimising bill costs.

The aggregator EMS implements optimised schedules for flexible loads, according to the outcomes of the optimisation.

The BO evaluates the savings on the energy bill, verifying that BU's QOE (quality of experience) has not been impacted.

Diagram (Create a schema where you show the actors and how they are connected)



INFORMATION *EXCHANGED*			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	Static TOU Electricity Prices (if applicable)	The Energy Services Company (ESCO) needs to collect the static TOU electricity price information from the electricity bill for each period of the day (e.g., peak hours, off-peak, etc…). Such information is provided by the Building Operator (BO) or the Electricity Retailer.	
2	Time periods for static TOU electricity bill (if applicable)	The ESCO needs to collect the information from the electricity bill on the time periods for each period of the day (e.g., peak hours, off-peak, etc…), and input it to the EMS. Such information is provided by the BO or the Electricity Retailer.	
3	Dynamic TOU Electricity Prices (if applicable)	EMS needs to have the dynamic electricity prices with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	

4	Forecasted Dynamic TOU Electricity Prices (if applicable)	EMS needs to have the forecasted dynamic electricity prices with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	
5	Disaggregated load consumption	EMS needs to have the disaggregated load consumption for buildings' assets with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	
6	Aggregated load consumption	EMS needs to have the aggregated load consumption of the building with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	
7	Set points and constraints for flexible assets	BO shall provide the ESCO with set points and constrains on flexible assets collected from Building Users (BU).	

INTEGRATION PROFILE		
Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement R-ID	***Requirement name***	***Requirement description***
1	Regulatory compliance	Operations conform to energy regulations and building standards
2	Data privacy	Adherence to GDPR for all data handling and processing
3	System security	Secure access to the EMS and protection against unauthorised access
4	Interoperability	Compatibility with existing infrastructure and new technologies.

REFERENCES

[1] ebIX®, EFET and ENTSO-E, The Harmonised Electricity Market Model, 2023

DEMO 2 - Business Use Case 5

SCOPE Peak shaving to minimise grid fees
Peak shaving to minimise grid fees.
This UC aims to minimise the grid fees for exceeding the contracted power in residential, commercial or industrial buildings featuring Distributed Energy Resources (DER), e.g., CHP, PV, or Energy Storage Systems (ESS), e.g., batteries, thermal storage. The goal is to use DER or ESS to perform peak shaving when the consumption is forecasted to surpass the contracted power. **Features under study:** Residential, commercial or industrial building Distributed Energy Resources (DER), if available Energy Storage Systems (ESS), if available Local EMS Aggregator EMS Controllable loads Networks/Markets under study: On-premises Network Retail market **Dependence on other BUCs:** Interaction with BUCs concerning buildings' energy flexibility.
BUSINESS OBJECTIVES (discrete objectives narrow scope): Minimise grid fees for exceeding the contracted power Flatten the load curve to reduce consumption peaks Maintain QOE (quality of experience) of all tenants and visitors of the building Minimise CO_2 emissions by enabling higher shares of renewable energy generation contribution to the energy mix.

ACTORS & ROLES, NAMES AND TYPES

ACTORS:

- Building owner
- Electricity Retailer
- Energy Services Company (ESCO) - A party offering energy-related services to the Party Connected to Grid, but not directly active in the energy value chain or the physical infrastructure itself. The ESCO may provide insight services as well as energy management services. [1]
- Tenants and visitors
- Technology Provider - Provides hardware or software technology for buildings' energy systems.

ROLES:

Building operator – manages the energy system of the building, making use of the EMS and relying on building's assets (from where flexibility will be extracted). (The actor could be the building owner).

SHORT DESCRIPTION

The Building Operator (BO) gathers information from tenants and visitors (hereinafter Building Users - BU) about desired comfort level and constraints concerning Distributed Energy Resources (DER), Energy Storage Systems (ESS) and controllable loads that may impact them (e.g., hot water produced by solar collectors, thermal storage of swimming pools, Electrical Vehicle Supply Equipment (EVSE), etc.).

The BO identifies new set points and constraints for DERs, ESSs and controllable loads according to the information collected and provides them to the Energy Services Company (ESCO).

The BO collects information on the contracted power and related grid fees from the Electricity Retailer (using the electricity bill).

The BO collects the disaggregated energy consumption measurements from all building users and local EMSs and provides them to the ESCO.

The BO collects the disaggregated energy consumption and production measurements from DESs and ESSs and provides them to the ESCO.

The ESCO inputs set points, constraints, energy consumption and production measurements to the aggregator EMS.

The ESCO develops a forecast tool to predict the energy consumption of the building.

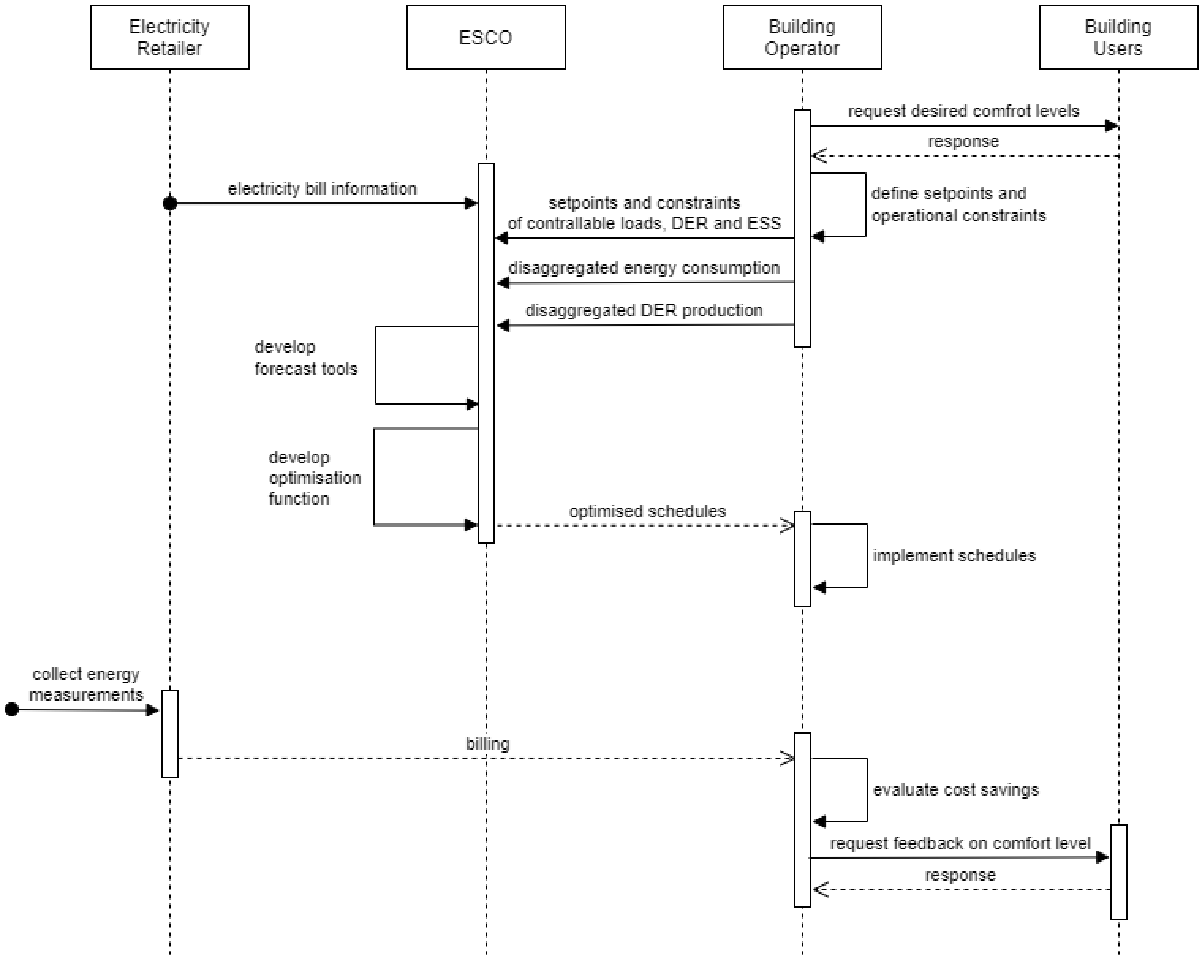
The ESCO develops a forecast tool to predict the energy production of the DERs, if non-dispatchable, e.g., PV, wind turbine.

The ESCO develops an optimisation function using metering data, set points of the DERs and ESSs, DERs forecasts if applicable, and contracted power, with the objective function of minimising the grid fees paid to the Electricity Retailer.

The aggregator EMS implements optimised schedules for DERs, ESSs and controllable loads, according to the outcomes of the optimisation.

The BO evaluates the savings on the grid fees, verifying that BU's QOE (quality of experience) has not been impacted.

Diagram



INFORMATION *EXCHANGED*			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	Contracted Power Information	The ESCO needs to collect the contracted power information (i.e., power, fees for exceeding the power) from the electricity bill and insert it in the EMS. Such information is provided by the Building Operator (BO) or the Electricity Retailer.	
2	Disaggregated load consumption	EMS needs to have the disaggregated load consumption of the building with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	
3	DER energy production	EMS needs to have the energy production of the DERs with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	
4	ESS energy production / consumption	EMS needs to have the energy production / consumption of the ESSs with a recommended resolution of at least 15 min. In case this is not achievable, the highest resolution available shall be used.	
5	RES energy forecast	EMS needs to have the range of the probabilistic energy forecast of on-site RES, if any.	

6	Set points and constraints for DER, ESS and controllable loads	BO shall provide the ESCO with set points and constraints on DER, ESS, and controllable loads, collected from Building Users (BU).	

INTEGRATION PROFILE		
Requirements *(optional)*		
Categories ID	***Category name for requirements***	***Category description***
Requirement R-ID	***Requirement name***	***Requirement description***
1	Regulatory compliance	Operations conform to energy regulations and building standards
2	Data privacy	Adherence to GDPR for all data handling and processing
3	System security	Secure access to the EMS and protection against unauthorised access
4	Interoperability	Compatibility with existing infrastructure and new technologies.

REFERENCES

[1] ebIX®, EFET and ENTSO-E, The Harmonised Electricity Market Model, 2023

DEMO 3 - Business Use Case 1

Note: In most of use cases target the increased self-sufficiency as it is in the strategic targets of the island of Krk and their municipal utilities. The “Connected BUC” refers to the first iteration of BUCs agreed at the workshop in Karlsruhe.

Using a seasonal water storage system based on potential energy of water and upgrading existing water infrastructure with energy

- We are looking at drinking water reservoir, utilizing "excess" energy available during from renewable sources during periods when the island is less burdened to operate water pumps to store the excess in hydro potential energy
- Double benefit: pumps operate at lower power during summer during energy shortages (when the demand is increased), plus there is the possibility of using small hydropower plants within the water supply for demand response and balancing, to recover a part of the energy stored in the potential energy of the water
- Very high required capital expenditures are partially mitigated - the reservoir lake and upper basins already exist and are being upgraded
- This is quite in line with self-sufficiency targets of the island – the potable water connection to the mainland exists, but is not cost-effective
- Source data comes from renewable energy sources production characteristics (with specific accent on *empty* buildings during the off-peak period that are effectively producers then), the users’ consumption, the data of water pump operation throughout the year and the meteorological data (both model and measured at local metering station); sister company of Smart Island Krk manages the water distribution so the dataset will be available for analysis
- A possible extension of the use case is to analyse the floating PV power plant

Connected BUC: **Increase self-sufficiency/ self-consumption**

DEMO 3 - Business Use Case 2

Note: In most of use cases target the increased self-sufficiency as it is in the strategic targets of the island of Krk and their municipal utilities. The “Connected BUC” refers to the first iteration of BUCs agreed at the workshop in Karlsruhe.

Meeting consumption needs through energy from the local energy community

- Owners of small PV systems and battery storage are being considered
- Avoiding the costs of buying electricity from suppliers – targeting the optimum at the community level
- Principal goal is to reduce the shared (syndicated) infrastructure cost for local people who bear the entire infrastructure burden
- This is a generalization of the above specific use case: this aims to cover all syndicated infrastructure cost and minimize capital expenditures while optimizing operation
- (Additional) source of income for owners of small PV systems while they are away so they (their buildings) have a mechanism to become contributors to local infrastructure although their dwellings are not used throughout the year

Connected BUC: **Increase self-sufficiency/ self-consumption** (at community level)

DEMO 3 - Business Use Case 3

Note: In most of use cases target the increased self-sufficiency as it is in the strategic targets of the island of Krk and their municipal utilities. The “Connected BUC” refers to the first iteration of BUCs agreed at the workshop in Karlsruhe.

Providing services to the transmission and distribution electricity grid through demand response

- Business buildings: opportunity in heating, ventilation, and cooling systems, as well as lighting
- Consumer-owned power plants without local consumption
- Empty buildings in the winter have the potential to provide services without considering comfort, solely focusing on revenue (and grid-side benefits)
- Two possible approaches: in both cases, potential increase in attractiveness for building smartness upgrades, due to financial benefits
    - Modelling the detailed impact of service provision on the grid: voltage regulation (providing services to the DSO through aggregators), frequency regulation (providing services to the TSO through aggregators)
    - Without detailed modelling of the impact of service provision on the grid: service provision modelled solely as potential revenue
- Three possible scenarios:
    - Performance and cost analysis of the building without providing demand response
    - Performance and cost analysis of the building with demand response through existing devices in the building (heating, ventilation, and cooling systems, lighting, appliances, etc.) and batteries and PV
    - Performance and cost analysis of the building with demand response through existing devices, but also with investment in a better dynamic building envelope (from facade materials to automated blinds and shutters, windows with light and heat entry damping, PV on the facade and as part of windows, etc.) to improve the building's characteristics as a thermal storage
    - HLUC2 and HLUC3 both link to increasing the attractiveness of investment (increased ROI) of smartness upgrades and building envelope upgrade in an ESCO-like business setting

Connected BUCs: **Multi-revenue generation by participating in the balancing market via aggregator, Participate in local flexibility markets, (Optimised local production self-consumption)**

DEMO 3 - Business Use Case 4

Note: In most of use cases target the increased self-sufficiency as it is in the strategic targets of the island of Krk and their municipal utilities. The “Connected BUC” refers to the first iteration of BUCs agreed at the workshop in Karlsruhe.

Production and (long-term) storage of hydrogen

- Excess production from small PV systems during periods of low demand is transformed into hydrogen using electrolyzers and stored in a hydrogen tank (when needed)
- Longer-term storage by converting “excess” electricity production into hydrogen, considered for use in local public transportation – ferry, local buses for ransit, waste management – predictable pattern of transportation asset usage
- This is more of a long shot compared to other HLUCs, however some unrelated projects and studies are ongoing on hydrogen in the vicinity of Krk so this will be considered as a companion HLUC to other ones

Connected BUC: **Increase self-sufficiency / Self-consumption** (at a broader level)

DEMO4 Business Use Case 1

SCOPE Increase PV self-consumption and dynamic tariff response
Describe briefly the scope and rationale of the UC.
The UC optimizes local self-consumption of photovoltaic (PV) in conjunction with dynamic electricity pricing. The objective is to manage the operation of the Carnot battery effectively within building infrastructure to minimize electricity costs. The scope includes the identification of requirements and functions necessary for the implementation of such a use case, with a focus on: • The integration of RES/PV systems to maximize on-site energy self-consumption. • The operation and optimization of the Carnot battery to leverage PV self-consumption and dynamic pricing mechanisms for enhancing economic efficiency and energy savings. • The evaluation of technological and economic benefits derived from the optimization and operation of the system. Features under study: RES/PV Building consumption Carnot battery EMS Dynamic tariff contract Networks/Markets under study: • MV Network Dependence on other BUCs:
BUSINESS OBJECTIVES (discrete objectives narrow scope): - Create optimal schedules for the Carnot battery - Maximize PV revenues by supplying energy when prices are high - Absorb grid energy surplus (low prices) and inject when shortage (high price) - Decrease total energy cost and maximize the welfare of apartment occupants

ACTORS & ROLES, NAMES AND TYPES

- DSO (smart meter)
- Facility manager
- Demo operator
- Building owner
- Building occupants
- IT solution providers (e.g. EMS)
- PV forecast provider
- Price forecast provider
- Load forecast provider

SHORT DESCRIPTION

Step wise approach: (Interactions between Actors and in certain cases with the systems/components)

1. The Energy Management system (EMS) collects forecasts of the dynamic electricity prices and grid tariffs for the day-ahead via API
2. The EMS collects PV forecast via API and compute load forecast
3. The EMS combined forecasted data and real-time status of the system to optimize the Carnot battery planning for the next day (15-min interval)
4. The EMS system collects real-time energy consumption and energy production measurements from all devices MQTT every 2 to 5 seconds, which is then stored in a cloud datahub
5. The EMS sends dispatch setpoints to the Carnot battery based on planning and real-time status of the system

Additional optional flows:

6. Intraday optimization: The system re-optimizes in intraday the planning when major deviations occur
7. Energy Consumption Analysis: System continuously monitors, records real-time energy usage data
8. Advanced Forecasting: Predictive models forecast future energy needs using historical data
9. Sustainable Energy Verification: Platform verifies real-time sustainability and origin of electricity
10. Intelligent storage efficiency calculator: System monitor electric storages to calculate real efficiency
11. Settlement: System calculates ex-post the real cost of electricity based on validated dynamic prices and grid tariffs

INFORMATION EXCHANGED			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	Electricity price forecast	EMS needs to have the electricity price forecast for the next 72h, with timestep of 15 minutes.	
2	Electricity price	EMS needs to have validated electricity price from the Entsoe Transparency Platform with timestep of 15 minutes.	
3	Grid tariff	EMS needs DSO grid tariffs	
4	Load live data	EMS needs to have live meter measurements of the load	
5	PV live data	EMS needs to have live meter measurements of the PV	
6	Load forecast	EMS needs to have a model for load forecast	
7	RES energy forecast	EMS needs to have the upper and lower limit of energy forecast	
8	Carnot battery BMS	Carnot battery provides power measurement data to the EMS	
9	Smart Meter data	EMS needs to have smart meter measurements of power from and to the site	

INTEGRATION PROFILE		
Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***

Requirement R-ID	***Requirement name***	***Requirement description***
1	DSO regulations	We need to conform with the law and energy regulations
2	GDPR	Personal data should be protected according to the GDPR
3	Cybersecure	The access to the service needs secure authentication
4	Level of control	Suggestion only/ human in the loop to decide/ consent management

DEMO4 Business Use Case 2

SCOPE Increase PV self-consumption and balancing market participation
Describe briefly the scope and rationale of the UC.
The UC co-optimizes local self-consumption of photovoltaic (PV) with participation in the balancing market. The focus is on managing the operation of Organic Rankine Cycle (ORC) of the Carnot battery to provide grid support during periods of system shortfall. The scope encompasses the following key areas: • Integration and Optimization: Detailed strategies for integrating RES/PV systems to maximize local energy self-consumption while leveraging ORC systems for enhanced grid support. This includes the use of advanced control systems to dynamically adjust the operation of ORC systems in response to grid demands and market signals. • Balancing Market Participation: The ORC operations in balancing market will be developed using historical data. • Economic and Technical Assessment: Evaluating the economic benefits and technical feasibility of simultaneous self-consumption of RES/PV energy and ORC participation in balancing market. This involves assessing the potential revenue streams from market participation alongside the savings from increased self-consumption. Features under study: RES/PV Building consumption Carnot battery EMS Balancing market Networks/Markets under study: • MV Network Dependence on other BUCs: • UC1
BUSINESS OBJECTIVES (discrete objectives narrow scope): - Create optimal schedules for the Carnot Battery - Co-optimize PV self-consumption and balancing market - Provide a support to the grid when the system is short, considering the ORC constraints and capabilities - Decrease total energy cost and maximize the welfare of apartment occupants

ACTORS & ROLES, NAMES AND TYPES

- DSO (smart meter)
- Facility manager
- Demo operator
- Building owner
- Building occupants
- IT solution providers (e.g. EMS)
- PV forecast provider

- Price forecast provider
- Load forecast provider
- Balancing service provider (aggregator)

SHORT DESCRIPTION

Step wise approach: (Interactions between Actors and in certain cases with the systems/components)

1. The Energy Management system collects energy prices and grid tariffs for the day-ahead via API
2. The EMS collects PV forecast and compute load forecast
3. The EMS combined day-ahead data and forecasted data to optimize the Carnot battery schedule, taking into account a participation in the balancing market
4. The EMS system collects real-time energy consumption and energy production measurements from all device MQTT every 2 – 5 seconds, which is then stored in a cloud datahub from the it service
5. The EMS collect in real-time TSO balancing signal
6. The EMS decides to change the ORC setpoint based on the balancing signal
7. The EMS sends dispatch setpoint to the Carnot battery
8. The EMS send back to the TSO the response to the balancing signal

Additional optional flows:

9. Intraday optimization: The system re-optimizes in intraday the planning when major deviations occur
10. Balancing market monitoring: System continuously monitors balancing participation
11. Advanced Forecasting: Predictive models forecast future balancing needs based on market trends

INFORMATION *EXCHANGED*

Information exchange, ID	*Name of information*	*Description of information exchanged*	*Requirement, R-IDs*
1	Electricity price forecast	EMS needs to have the electricity price forecast for the next 72h, with timestep of 15 minutes.	
2	Electricity price	EMS needs to have validated electricity price from the Entsoe Transparency Platform with timestep of 15 minutes.	
3	Grid tariff	EMS needs DSO grid tariffs	
4	Load live data	EMS needs to have live meter measurements of the load	
5	PV live data	EMS needs to have live meter measurements of the PV	
6	TSO balancing signal	EMS needs to have permanent access to balancing signal	
7	Load forecast	EMS needs to have a model for load forecast	
8	RES energy forecast	EMS needs to have the upper and lower limit of energy forecast	
9	Carnot battery BMS	Carnot battery provides power measurement data to the EMS	
10	Smart Meter data	EMS needs to have smart meter measurements of power from and to the site	

INTEGRATION PROFILE		
Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement R-ID	***Requirement name***	***Requirement description***
1	DSO regulations	We need to conform with the law and energy regulations
2	GDPR	Personal data should be protected according to the GDPR
3	Cybersecure	The access to the service needs secure authentification
4	Level of control	Suggestion only/ human in the loop to decide/ consent management
5	TSO regulations	We need to conform with the Terms and Conditions of the balancing market

DEMO 4 - Business Use Case 3

SCOPE Provide congestion relief to the DSO
Describe briefly the scope and rationale of the UC.
The UC aimed at providing grid services to the Distribution System Operator (DSO) for the purpose of congestion relief. This involves leveraging renewable energy sources (RES), particularly photovoltaic (PV) systems, and energy management technologies like Organic Rankine Cycle (ORC) systems to enhance grid stability and efficiency. Key areas covered in the scope include: • Grid Services Integration: Outlining strategies for integrating RES/PV and ORC systems to contribute effectively to grid congestion relief. This includes optimizing these systems to respond dynamically to grid congestion signals from the DSO. • Operational Coordination: Describing the operational coordination necessary between the energy systems and the DSO, focusing on real-time communication and data exchange to facilitate timely and effective grid support. • Technical and Economic Evaluation: Evaluating the technical solutions and economic implications of providing congestion relief services. This involves analyzing the potential impact on grid stability, the feasibility of implementation, and the financial benefits or costs associated with such services. Features under study: RES/PV Building consumption Carnot battery EMS DSO grid services Networks/Markets under study: • MV Network Dependence on other BUCs: • UC1
BUSINESS OBJECTIVES (discrete objectives narrow scope): - Provide a support to the distribution grid operator in the event of congestion, considering the ORC constraints and capabilities - Create optimal schedules for the Carnot Battery - Co-optimize PV self-consumption and DSO grid services - Decrease total energy cost and maximize the welfare of apartment occupants

ACTORS & ROLES, NAMES AND TYPES

- DSO (smart meter)
- Facility manager
- Demo operator
- Building owner
- Building occupants
- IT solution providers (e.g. EMS)

- PV forecast provider
- Price forecast provider
- Load forecast provider
- DSO (grid services)

SHORT DESCRIPTION

Step wise approach: (Interactions between Actors and in certain cases with the systems/components)

1. The Energy Management system collects energy prices and grid tariffs for the day-ahead via API
2. The EMS collects PV forecast and compute load forecast
3. The EMS combined day-ahead data and forecasted data to optimize the Carnot battery schedule, taking into account a participation in DSO grid services
4. The EMS system collects real-time energy consumption and energy production measurements from all device MQTT every 2 – 5 seconds, which is then stored in a cloud datahub from the it service
5. The EMS collect in real-time DSO congestion signal
6. The EMS decides to change the ORC setpoint based on the congestion signal
7. The EMS sends dispatch setpoint to the Carnot battery
8. The EMS send back to the DSO the response to the congestion signal

Additional optional flows:

9. Intraday optimization: The system re-optimizes in intraday the planning when major deviations occur

INFORMATION *EXCHANGED*			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	Electricity price forecast	EMS needs to have the electricity price forecast for the next 72h, with timestep of 15 minutes.	
2	Electricity price	EMS needs to have validated electricity price from the Entsoe Transparency Platform with timestep of 15 minutes.	
3	Grid tariff	EMS needs DSO grid tariffs	
4	Load live data	EMS needs to have live meter measurements of the load	
5	PV live data	EMS needs to have live meter measurements of the PV	
6	DSO congestion signal	EMS needs to have permanent access to congestion signal	
7	Load forecast	EMS needs to have a model for load forecast	
8	RES energy forecast	EMS needs to have the upper and lower limit of energy forecast	
9	Carnot battery BMS	Carnot battery provides power measurement data to the EMS	

10	Smart Meter data	EMS needs to have smart meter measurements of power from and to the site	

INTEGRATION PROFILE		
Requirements *(optional)*		
Categories ID	***Category name for requirements***	***Category description***
Requirement R-ID	***Requirement name***	***Requirement description***
1	DSO regulations	We need to conform with the law and energy regulations
2	GDPR	Personal data should be protected according to the GDPR
3	Cybersecure	The access to the service needs secure authentification
4	Level of control	Suggestion only/ human in the loop to decide/ consent management
5	DSO grid services	We need to conform with the Terms and Conditions of the DSO grid services

DEMO 5 - Business Use Case 1

SCOPE Optimization of energy consumption in the REC
Describe briefly the scope and rationale of the UC.
This UC consist of the optimization of energy consumption within the REC, with the objective of improving the efficiency of REC buildings individually and optimizing energy consumption for the REC as a whole. Specifically, the use case focuses on deploying a digital platform based on the Operational Layer of W-IBRA. **Features under study:** - Residential and public buildings - RES - Digital platform Networks/Markets under study: LV Network **Dependence on other BUCs:**
BUSINESS OBJECTIVES (discrete objectives narrow scope): - Energy Optimization Services - Renewable Energy Community Management - Minimising over-consumption - Minimise CO2 emissions - Optimize the use of the energy

ACTORS&ROLES, NAMES AND TYPES

DSO/DEMO leader: Cuerva will ensure the integration of the digital platform with the distribution network to ensure the operation.

Public Authorities/Users

Energy Community Operator

Technology Provider

Project Coordinator

SHORT DESCRIPTION

Step wise approach:

- Development and deployment of the digital platform in alignment with W-IBRA standards for the optimization of energy consumption within the REC.
- Integration of the digital platform with the distribution network by DSO.
- The Energy Community Operator conducts detailed analyses of REC energy consumption patterns to inform optimization strategies.
- Oversee the implementation process.

INFORMATION EXCHANGED			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	DSO role	Cuerva, acting as the Distribution System Operator (DSO) and Demo leader, will ensure seamless integration of the digital platform with the distribution network, facilitating efficient operation within the Renewable Energy Community (REC)	
2	Energy Community Operator	Vergy, functioning as the Energy Community Operator, will conduct in-depth analyses of REC energy consumption patterns. These insights will inform optimization strategies aimed at enhancing overall efficiency within the community	
3	Development and deployment of the digital platform	Schneider Electric, serving as the Technology Provider, will spearhead the development and deployment of the digital platform in alignment with W-IBRA standards. Their expertise will ensure the platform's robustness and effectiveness in meeting REC needs.	

DEMO 5 - Business Use Case 2

SCOPE Enabling REC participants to provide flexibility services to the DSO for grid stability and energy optimization
Describe briefly the scope and rationale of the UC.
This UC tries to enable Renewable Energy Community participants to provide flexibility services to the DSO, enhancing grid stability and optimizing energy flow. Features under study: - DSO - REC - Flexibility services - Grid stability Networks/Markets under study: LV Network Dependence on other BUCs:
BUSINESS OBJECTIVES (discrete objectives narrow scope): - Grid stability enhancement - Optimizing energy flow - Flexibility services provision

ACTORS&ROLES, NAMES AND TYPES

DSO/Demo Leader: Cuerva coordinate with REC occupants and aggregator to enable their participation in offering flexibility services to the DSO.

REC Participants

Energy Community Operator

Aggregator

SHORT DESCRIPTION

Step wise approach:

Coordination and cooperation among REC participants, aggregators, and key industry players.

REC building occupants and aggregators will enhance grid stability and optimize energy flow by adjusting energy consumption patterns and deploying distributed energy resources (DERs),

Energy Community Operator provide insights into REC energy consumption patterns and support the optimization of flexibility services offered by REC participants.

Aggregator facilitates the participation of REC building occupants in offering flexibility services to the DSO.
DSO coordinate with REC occupants and aggregator to enable their participation in offering flexibility services to the DSO.

INTEGRATION PROFILE			
		Information exchanged	
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	REC Energy consumption patterns	Characteristics and consumption of REC. Energy community operator provide this information	
2	Flexibility services to the DSO	Different types of services to improve the flexibility in the DSO by participation of REC building occupants. Coordinate with REC occupants and aggregators	

DEMO5 Business Use Case 3

SCOPE Optimization of energy consumption in the REC
Describe briefly the scope and rationale of the UC.
This UC tries to determine future investments in innovative technologies that enhance the grid and REC capacity to interoperate with the DSO and markets. **Features under study:** - REC capacity - Markets - DSO - Grid stability - New technologies **Networks/Markets under study:** LV Network Dependence on other BUCs:
BUSINESS OBJECTIVES (discrete objectives narrow scope): - Smart contracts - Enhanced grid stability and interoperability

ACTORS & ROLES, NAMES AND TYPES

DSO: Collaborate to integrate innovative technologies into grid management strategies for enhanced interoperability.

Energy Community Operator

Technology partner

Researchers

SHORT DESCRIPTION

Step wise approach:

Vergy's data insights and analysis on REC energy consumption patterns provide valuable inputs for identifying investment opportunities that align with REC needs and objectives.

Through the deployment of advanced AI algorithms developed by AIR, RECs can benefit from precise energy forecasting and optimization capabilities, thereby improving overall energy management efficiency.

LIST contributes its expertise in energy systems modeling to enhance the accuracy of forecasting models, enabling more informed decision-making on investment strategies.

Cuerva, as the DSO, plays a crucial role in collaborating with technology partners to integrate innovative solutions into grid management strategies. By fostering interoperability between emerging technologies and existing grid infrastructure, Cuerva Energía aims to enhance grid stability, optimize energy flow dynamics, and facilitate seamless integration of RECs with the broader energy ecosystem.

UMA, as a research institution, conducts in-depth research and testing on emerging technologies to assess their viability and potential impact on grid and REC capacity enhancement. By evaluating the feasibility and performance of various technological innovations, UMA contributes valuable insights to the decision-making process, ensuring that investments align with the long-term goals and objectives of the REC and broader energy community.

INFORMATION EXCHANGED			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	Data insights on REC energy consumption patterns	To determine the consumption behaviour of REC.	
2	Energy model forecasting	Obtained through energy systems modelling. Improve accuracy to make more informed decisions.	
3	Existing grid infrastructure	By fostering interoperability between emerging technologies and existing grid infrastructure to enhance grid stabilit and optimize energy flow dynamics.	

DEMO 6 - Business Use Case 1

SCOPE Get compensated for providing an interface to sell balancing power
Describe briefly the scope and rationale of the UC.
The transmission system operator (TSO) responsible for the balancing area needs to ensure a match of consumption and production (which manifests itself in the grid frequency). Different reserves exist, targeting different fastness of response after a disturbance. Assets in buildings can provide those reserves. Offering interfaces for Aggregators or TSO **Features under study:** - (bidirectional) charging stations - battery storage **Networks/Markets under study:** - balancing power markets - across all voltage levels **Dependence on other BUCs:**
BUSINESS OBJECTIVES (discrete objectives narrow scope): *- Generate income from offering balancing power* *- Sell ability of building to react on balancing demand to Aggregator or TSO* *- Enable assets in the building to deliver the service sold (eighter follow setpoints of TSO or control its feed-in or consumption autonomously depending on local grid state)*

ACTORS&ROLES, NAMES AND TYPES

District manager (BES for Karlsruhe)
Charging point operator (InnoCharge GmbH for Karlsruhe)
(external requester) Transmission system operator (TransnetBW for Karlsruhe)
(external requester) Aggregator (InnoCharge GmbH for Karlsruhe)

SHORT DESCRIPTION

The assets in the build need to have a defined interface over which balancing request can be communicated to the asset. The concrete contract for the compensation needs to be defined in the future. This use-case focusses on providing the interface for assets to receive set-points.

Step-wise approach:

Measure with 1-4 second resolution in battery or charging station
Measure frequency with not more than 10mHz uncertainty in the battery
Capturing of operating point profile, realized power profile, target value profile
Receiving of set points request and reaction of the asset
Changing the power consumption / feed-in of the asset according to the set points

INFORMATION EXCHANGED			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	Set point request for secondary reserve	Receive a message that an aggregator or TSO would send with a reserve request and set points. Sender as mock-up, realization in district real	
2	Price for current day	Price for generally offering potential of realizable reserve (Leistungspreis) Price for produced energy (Arbeitspreis)	
3	Request for primary reserve provision	Receive a message aggregator or TSO would send to request primary reserve reservation / activation	

INTEGRATION PROFILE		
Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement R-ID	***Requirement name***	***Requirement description***
1	TSO regulations	Like PQ-Bedingungen für FCR, aFRR und mFRR in Germany or diverse checklists, see: https://www.regelleistung.net/de-de/Infos-f%C3%BCr-Anbieter/Wie-werde-ich-Regelenergieanbieter-Pr%C3%A4qualifikation#dnn_ctr933_ModuleContent
2	EU Regulations	PICASSO (EU market for aFRR)

DEMO 6 - Business Use Case 2

SCOPE Price optimization for the energy consumed and provided in a district via dynamic tariffs
Describe briefly the scope and rationale of the UC.
This UC tries to minimise the cost of energy consumption whilst maximizing the profit from supplying electricity to the grid/selling electricity to the market. This could in extreme cases also mean to charge a battery with grid electricity instead of the RES energy. **Features under study:** Residential building RES (PV, CHP) Batteries - stationary and mobile (Electric Vehicles) EMS Controllable loads (battery, charging infrastructure, HVAC) **Networks/Markets under study:** LV Network MV Network Comparison to standard electricity concepts **Dependence on other BUCs:**
BUSINESS OBJECTIVES (discrete objectives narrow scope): • Total electricity invoice sum in € (as low as possible) • Total electricity feed-in sum in € (as high as possible) • Percentage of remaining battery capacity (within acceptable wear and tear)

ACTORS&ROLES, NAMES AND TYPES

DSO
Electricity Retailer
Demo operators
Building owner
Building operator/administration
Facility manager
RES operator
Battery operator
Charge Point Operator (CPO)
Electric vehicle owners
Tenants
IT network operator

SHORT DESCRIPTION

Step wise approach:

Current & forecasted Data of the load profiles (real-time/15-Minute cycle)
Current & forecasted Data of the RES production (real-time/15-Minute cycle)
Data of the battery´s SoC
Current & prognosed electricity prices (supply & demand)
Implementation in the existing EMS of the energy district
Timetable calculation
Adjustment of controllable loads and on-demand supply (stationary & mobile batteries)

INFORMATION EXCHANGED

Information exchange, ID	*Name of information*	*Description of information exchanged*	*Requirement, R-IDs*
1	RES energy forecast	EMS needs to have the upper and lower limit of energy forecast from the Open Energy Service	
2	Aggregated load forecast	EMS needs to have the aggregated load forecast	
3	Disaggregated load forecast	EMS needs to have the disaggregated load forecast from the devices of controllable loads	
4	Power measurement data	EMS needs to have actual measurements of power from and to the site	
5	Feed-in tariff	EMS needs to have the current price for electricity supplied to the grid	
6	Electricity price	EMS needs to have the electricity price information from the existing electricity supplier every 15 minutes.	
7	Electricity price from competitors	EMS needs to have the electricity price information from electricity supplier competitors at the same interval	
8	Health status of the batteries	Remaining percentage of the usable battery capacity	

INTEGRATION PROFILE

Requirements *(optional)*

Categories ID	*Category name for requirements*	*Category description*

Requirement R-ID	*Requirement name*	*Requirement description*
1	DSO regulations	We need to be conform with the law and energy regulations
2	Energy performance	To be defined with stakeholders e. g. minimal room temperature 21 C°, EV is getting charged at least 20 kWh in the first 3 hours or 50 kWh within 8 hours
3	GDPR	Personal data should be protected according to the GDPR
4	Cybersecure	The access to the service needs to be password protected.
5	Level of control	Suggestion only/ human in the loop to decide/ consent management

DEMO 6 - Business Use Case 3

SCOPE
Realize dynamic DSO limitations during bottlenecks (§ 14a EnWG)

Describe briefly the scope and rationale of the UC.

This UC implements a relatively new regulatory requirement in Germany to reduce the power drawn from the grid to a certain value for new charging stations, heat pumps or batteries if necessary. This UC can be combined with other UCs using EMS.

Features under study:
Residential building
RES
Battery
EMS
Charging station
Heat pump
Smart Meter Gateway and Control Unit

Networks/Markets under study:
- **LV Network**

Dependence on other BUCs:

BUSINESS OBJECTIVES (discrete objectives narrow scope):
- **reduce grid fees**
- **implement regulatory requirements efficiently by EMS**

ACTORS & ROLES, NAMES AND TYPES

- Building operator
- Facility manager
- Demo operator
- Retailer
- Tenants
- Electric vehicle owner
- Car sharing company
- Building owner
- DSO
- Metering Point Operator

SHORT DESCRIPTION

Step wise approach: (Interactions between Actors and in certain cases with the systems/components)

1. The DSO monitors the load in the LV grid and calculates limitation signals if necessary
2. If a limitation is necessary, the DSO sends the limitation signal to the metering point operator
3. The metering point operator passes the limitation via the smart meter gateway (SMGW) of the building to either a control unit or directly to the building EMS
4. The building EMS receives the signal either directly from the smart meter gateway (SMGW) or from the control unit
5. The EMS immediately adjusts the schedules of the charging processes, heat pumps and/or batteries w.r.t the limitation signal
6. The new schedules are deployed to the flexible loads and/or batteries.

INFORMATION EXCHANGED

Information exchange, ID	*Name of information*	*Description of information exchanged*	*Requirement, R-IDs*
1	Limitation signal	EMS needs to have the limitation signal from the DSO (in percent of the installed flexible power). This limits the power of certain flexible load that is to be allowed to draw from the grid during a defined timespan	
2	Actual power of flexible loads	EMS needs to have the actual measured power of the flexible devices.	
3	Power at the grid connection point	EMS needs to have the actual measured power at the grid connection point of the building to calculate the power that the flexible devices draw from the grid.	

INTEGRATION PROFILE

Requirements (optional)

Categories ID	*Category name for requirements*	*Category description*
Requirement R-ID	***Requirement name***	***Requirement description***
1	DSO regulations	We need to conform with the law and energy regulations

DEMO 6 - Business Use Case 4

SCOPE Limit power at the grid connection point (GCP)
Describe briefly the scope and rationale of the UC.
This UC limits the peak power of the building drawn from the grid with the goal to avoid grid expansion costs. **Features under study:** **Residential building** **RES** **Battery** **EMS** **Charging station** **Heat pump** **Networks/Markets under study:** ● **LV Network** ● **MV Network** **Dependence on other BUCs:**
BUSINESS OBJECTIVES (discrete objectives narrow scope): - **reduce grid fees** - **reduce local grid expansion costs (e.g. a new transformer)**

ACTORS & ROLES, NAMES AND TYPES

- Building operator
- Facility manager
- Demo operator
- Retailer
- Tenants
- Electric vehicle owner
- Car sharing company
- Building owner
- DSO
- Metering Point Operator

SHORT DESCRIPTION

Step wise approach: (Interactions between Actors and in certain cases with the systems/components)

7. The EMS monitors the power at the grid connection point and calculates short-term predictions
8. If the short-term predictions imply that the power drawn from the grid will peak, then flexibility gets activated to avoid or at least minimize the peak
9. Schedules of flexible loads are adjusted by the EMS and deployed to the devices
10. Optional: A local controller monitors the power at the GCP in real-time and locally adjusts the power of flexible devices to minimize peaks (without new schedules)

INFORMATION EXCHANGED			
Information exchange, ID	***Name of information***	***Description of information exchanged***	***Requirement, R-IDs***
1	Actual power of flexible loads	EMS needs to have the actual measured power of the flexible devices.	
2	Power at the grid connection point	EMS needs to have the actual measured power at the grid connection point of the building to calculate the power that the flexible devices draw from the grid.	
3	Maximum power at the grid connection point	The EMS needs a threshold of the power at the GCP that leads to flexibility activation	

INTEGRATION PROFILE		
Requirements (optional)		
Categories ID	***Category name for requirements***	***Category description***
Requirement R-ID	***Requirement name***	***Requirement description***
1	DSO regulations	We need to conform with the law and energy regulations

DEMO 6 - Business Use Case 5

SCOPE Increase self-sufficiency/ self-consumption
Describe briefly the scope and rationale of the UC.
This UC tries to minimise the input of electricity from the grid by using locally produced RES (from e. g. PV or CHP) and managing controllable loads to achieve a high environmental standard and fulfil a strongly prioritized long term monetary risk management. **Features under study:** Residential building RES (PV, CHP) Batteries - stationary and mobile (bidirectional charging of EV) EMS Controllable loads (battery, charging infrastructure, HVAC) **Networks/Markets under study:** LV Network MV Network Comparison to standard electricity concepts **Dependence on other BUCs:**
BUSINESS OBJECTIVES (discrete objectives narrow scope): • CO2 emissions (towards net zero district / national high standard eco-certificate) • Ratio of own power consumption (as high as possible) • Mismatches of own power supply and demand in kWh and number of incidents (as low as possible)

ACTORS&ROLES, NAMES AND TYPES

DSO
Demo operators
Building owner
Building operator/administration
Facility manager
RES operator
Charge Point Operator (CPO)
Electric vehicle owners
Tenants
IT network operator
Retailer

SHORT DESCRIPTION

Step wise approach:
1. Current & forecasted Data of the load profiles (real-time/15-Minute cycle)
2. Current & forecasted Data of the RES production (real-time/15-Minute cycle)
3. Current electricity price from competitors
4. Data of the batteries´ SoC
5. Implementation in the existing EMS of the energy district
6. Timetable calculation
7. Adjustment of controllable loads and on-demand supply (stationary & mobile batteries)
8. Annual analysis of total electricity costs compared to standard electricity concepts.

INFORMATION EXCHANGED

Information exchange, ID	*Name of information*	*Description of information exchanged*	*Requirement, R-IDs*
1	RES energy forecast	EMS needs to have the upper and lower limit of energy forecast from the Open Energy Service	
2	Aggregated load forecast	EMS needs to have the aggregated load forecast from the devices	
3	Disaggregated load forecast	EMS needs to have the disaggregated load forecast from the devices of controllable loads	
4	Power measurement data	EMS needs to have actual measurements of power from and to the site	
5	Feed-in tariff	EMS needs to have the current price for electricity supplied to the grid	
6	Electricity price	EMS needs to have the electricity price information from the existing electricity supplier every 15 minutes.	
7	Electricity price from competitors	EMS needs to have the electricity price information from electricity supplier competitors at the same interval	
8	Health status of the batteries	Remaining percentage of the usable battery capacity	

INTEGRATION PROFILE

Requirements (optional)

Categories ID	*Category name for requirements*	*Category description*
Requirement R-ID	***Requirement name***	***Requirement description***
1	DSO regulations	We need to be conform with the law and energy regulations

2	Energy performance	To be defined with stakeholders e. g. minimal room temperature 21 C°, EV is getting charged at least 20 kWh in the first 3 hours or 50 kWh within 8 hours
3	GDPR	Personal data should be protected according to the GDPR
4	Cybersecure	The access to the service needs to be password protected.
5	Level of control	Suggestion only/ human in the loop to decide/ consent management