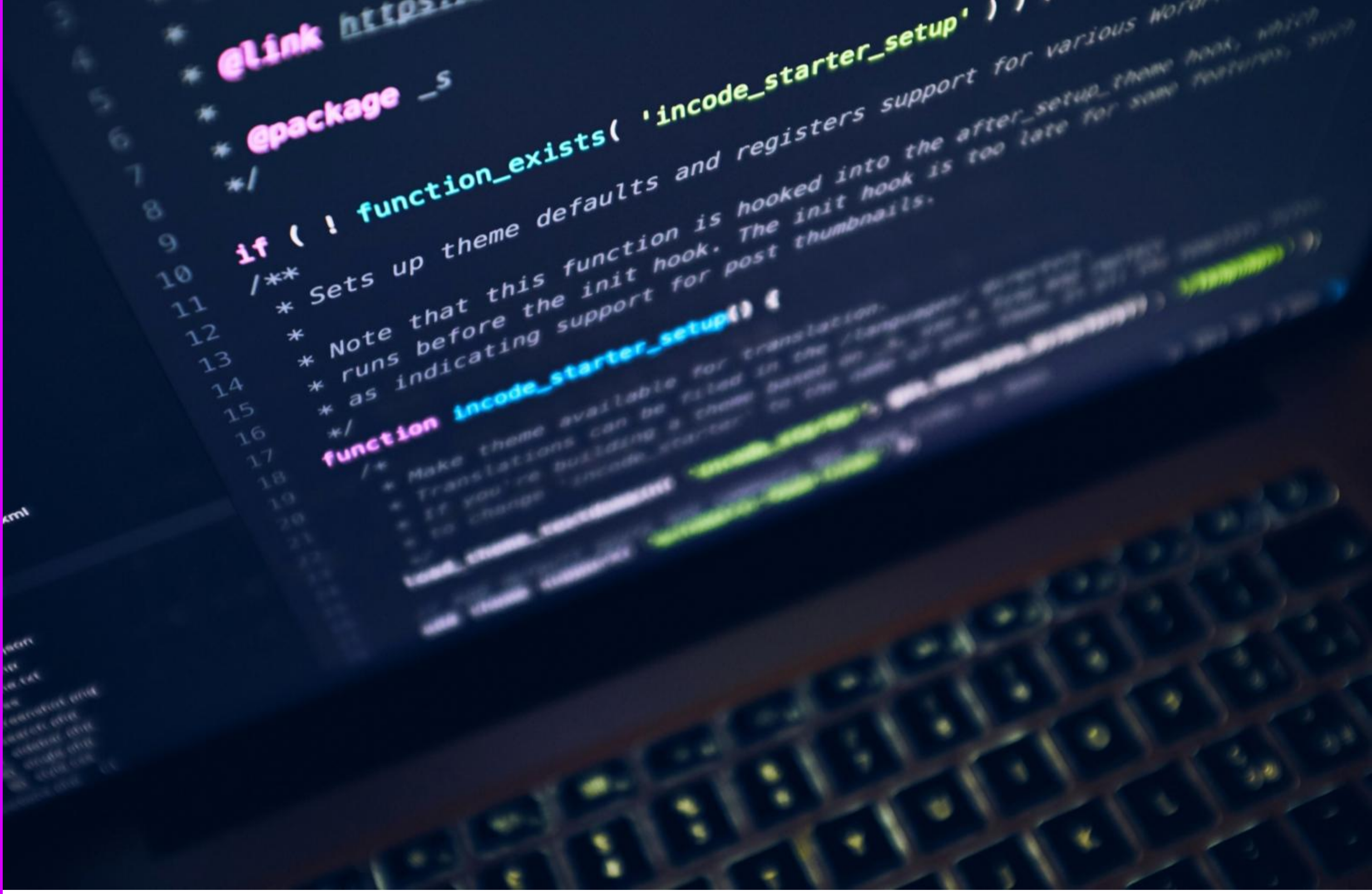

InEExS
ENERGY SERVICES ON THE BLOCKCHAIN

Technology Experience Package

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EXECUTIVE SUMMARY

This report focuses on facilitating the adoption of new energy service business models by engaging key stakeholders, including small and medium-sized enterprises (SMEs), public authorities, and citizen associations. Through capacity-building activities, the project aims to strengthen collaborations between Business Cases (BCs) and Replicators, ensuring effective knowledge transfer and market adoption of smart grid solutions. A core component of this effort is the **Technology Experience Package (TEP)**, which provides a structured blueprint for replicating business models in both economic and technical contexts.

TEP offers a comprehensive analysis of technology experiences within the InEExS project, assessing the interplay between business models, technological readiness, replication potential, and smart grid architecture. Through the exploration of four distinct business models, the report highlights how innovative value propositions can drive the adoption of smart grid solutions while addressing economic, regulatory, and operational considerations. The assessment of "Technology Readiness Levels" (TRLs) identifies the maturity of key smart grid technologies, providing insights into their current deployment status and the challenges associated with scalability. By mapping TRLs across different business models, critical gaps and potential areas for further development have been identified to accelerate market adoption.

Additionally, the replication potential of these business models has been thoroughly analysed, evaluating the feasibility of scaling smart grid solutions across various EU regions. Factors such as regulatory alignment, infrastructure compatibility, and stakeholder engagement play a crucial role in determining the successful replication of these innovations. While some models can be transferred seamlessly, others require localised adaptations to fit specific market conditions. To ensure technical feasibility and integration, each business model has been mapped using the Smart Grid Architecture Model (SGAM), which offers a structured and standardised approach to understanding the component, communication, information, function, and business layers of the proposed solutions. This ensures interoperability, alignment with existing grid infrastructures, and compliance with EU energy policies and digitalization strategies.

To support the large-scale deployment of these solutions, the project will undertake several key activities. Training content and materials will be developed based on insights from previous work packages, ensuring a structured and effective transfer of knowledge. The definition of learning outcomes will guide capacity-building efforts, enabling stakeholders to gain a comprehensive understanding of the business models and their applications. Workshops will be conducted to facilitate hands-on learning, with an evaluation process in place to assess their effectiveness and refine future training programs.

By combining technological insights, business model development, and targeted capacity-building initiatives, this Technology Experience Package aims to accelerate market adoption and enable stakeholders to leverage smart grid innovations effectively. Moving forward, continuous collaboration between policymakers, industry leaders, and technology providers will be essential to overcoming barriers and unlocking the full potential of these new energy business models across Europe.

GLOSSARY

API	Application Programming Interface
BPL	Broadband over Power Line
CEN	European Committee for Standardization (Comité Européen de Normalisation)
CENELEC	European Committee for Electrotechnical Standardization
CO2	Corbon Dioxide
DER	Distributed Energy Resources
EMS	Energy Management System
ETH	Ethernet
ETSI	European Telecommunications Standard Institute
GDPR	General Data Protection Regulation
HVAC	Heating, Ventilation, and Air Conditioning
IEC	International Electronic Commission
IP	Internet Protocol
ISO	International Organization for Standardization
KPI	Key Performance Indicators
LoRA	Long Range
MQTT	Message Queuing Telemetry Transport
MRV	Monitoring, Reporting and Verification
OPC UA	Open Platform Communications Unified Architecture
PBP	Payback Period
PV	Photovoltaics
P4P	Pay4Performance
REST	Representational State Transfer
ROI	Return on Investment
SME	Small and medium-sized enterprises
TC	Technical Committee
TCP	Transmission Control Protocol
TEP	Technology Experience Package
WAN	Wide Area Network
Wi-Fi	Wireless Fidelity

Introduction

The InEExS project aims to revolutionise energy services by deploying integrated solutions across sectors and carriers. InEExS focuses on providing integrated energy services that span various sectors and energy carriers. By connecting these services, the project aims to enhance energy efficiency and sustainability. At the same time, the project leverages blockchain technology to tokenise energy-saving data. This enables cooperation among different market segments and actors, fostering collaboration and innovation. InEExS emphasizes the development of business models and contractual frameworks that facilitate the implementation of smart energy services. These models include renewable and distributed energy resources, such as electromobility, heat pumps, solar panels etc. Finally, the project brings together diverse market actors, including utilities, energy communities, energy agencies, and technology providers. Through distributed ledger technology and smart contracts, these actors collaborate to create a seamless energy ecosystem.

In total, four business cases (BC) were elaborated between the project partners, namely BC1 "Recommendations for innovative energy contracts with Pay4Performance (P4P) guarantees," BC2 "Improved self-consumption of DER in Energy Communities," BC3 "Energy Efficiency and flexibility services for legacy natural gas boilers," as well as BC4 "Smart energy management for EV charges and electricity-based HVAC appliances." All business cases were further elaborated in Work Package (WP) 2 and are shortly explained in the following:

BC1 focuses on sector coupling in the energy sector using a building complex with solar power production on the roof. The energy is used to charge electric vehicles in the garage of the building or supply residential units. The BC aims to maximise solar power usage by using an app that tracks and visualises energy data for residents. The app will encourage behaviour changes by informing users when solar power is at peak production and suggesting ways to optimize usage.

BC2 aims to empower residential households to become prosumers that produce and consume their own renewable energy. By joining energy cooperatives, prosumers benefit from shared resources, lower costs, and better services. The initiative focuses on enhancing the self-consumption of distributed energy resources (DER), like solar panels and batteries, through incentivisation mechanisms, using smart technologies. This helps to reduce energy bills, increase security and support renewable energy integration into the grid.

BC3 focuses on the management of space heating consumption in households, by actively controlling and optimizing the indoor environment, with the aim of (a) improving their energy efficiency through load reduction, while respecting their comfort limits (b) evaluating the achieved energy savings at the residential consumer portfolio level, c) contributing to the energy efficiency obligations of the energy supplier.

BC4 is about the development of a smart energy management for EV chargers and electricity-based HVAC appliances. This smart energy management is a system that optimizes the existing charging infrastructure for electric vehicles by using different technical solutions. The system can be used to manage the charging of electric vehicles in a way that minimizes the impact on the grid and reduces the cost of charging.

This technology experience package (TEP) provides a comprehensive record of the partner's interactions with various technologies throughout the project. Its purpose is to document and reflect on these experiences, capturing detailed insights into how the technologies were used and perceived. By systematically documenting their technological experiences, partner organisations are enabled to critically reflect on their development throughout the project and derive insights for future initiatives. The TEP serves as a tool for tracking individual and collective learning progress, including the acquisition of new skills, increased familiarity with specific software or hardware, and engagement with a range of technological tools. In addition to supporting learning and professional development, the document contributes to effective project management by outlining the technologies employed, lessons learned, and emerging best practices. Furthermore, the structured sharing of technological experiences enhances collaboration within the project, promoting mutual learning and the dissemination of knowledge across teams.

The TEP aims to serve all involved parties in the project in order to benefit from the experiences gained through the utilization of technologies. This document is intended not only for the project partners but also for external stakeholders who are not directly involved in the project yet seek to apply similar technologies within their specific areas of interest. Consequently, both project partners and third-party organisations may utilize and replicate the outcomes presented herein for application in other related initiatives.

In terms of its scope, this document presents the TEP as a comprehensive blueprint for business solutions. It offers detailed insights into the replication of business cases across technical, economic, legal, and operational dimensions, thereby serving as a structured guide for the implementation of similar initiatives. The conclusions presented in this document are intended to inform and guide the application of sector-coupling technologies as a means to enhance energy efficiency.

After this introduction, section 2 provides an overview of the technological experiences associated with the four business cases. This section offers a general description of how the respective technologies have been implemented within the project context.

Section 3 evaluates the technological maturity of the solutions applied, using the Technology Readiness Level (TRL) model. The TRL framework, which ranges from TRL 1 (basic principles observed) to TRL 9 (actual system proven in operational environment), is employed to assess the development stage of each technology. This section presents a comprehensive overview of the TRL levels assigned to the different technologies utilized in the project.

Section 4 outlines a detailed blueprint of the technologies embedded within the business models. It includes considerations for replication potential and integrates the Smart Grid Architecture Model (SGAM) to illustrate the system architecture and interoperability aspects.

Finally, Section 5 presents the conclusions drawn from the analysis, summarizing key findings and implications for the use of these technologies in future applications.

1 Technology Experience

This section addresses the application of established technologies within business models, encompassing a broad spectrum between software and hardware systems implemented in the InEExS project. This section is divided into the four different BCs developed throughout the project.

1.1 BC1: Recommendations for innovative energy contracts with P4P guarantees

Software (Intangible products, including computer programs and applications) used in BC1:

- **Meteocontrol** is an online platform that is able to monitor, control and manage data within their cloud services. The platform focuses on the monitoring of photovoltaic systems as well as the proper operation of photovoltaic systems. Measurement data, satellite images and weather forecasts are fed into the calculations of Meteocontrol to create yield forecasts and optimise them by using machine learning models. Customers of the platform are able to use a cloud-based monitoring platform, named VCOM (virtual control room) in order to monitor and control their PV consumption etc. VCOM provides an intuitive and easy-to-use API interface. This interface can be used to retrieve measurement data and technical data from the systems and network VCOM with other systems such as ERP solutions.
- **Chargecloud** is a provider of software solutions for electromobility. Chargecloud facilitates the control, networking, and management of electric vehicle (EV) charging infrastructure. This cloud-based software solution for electromobility provides comprehensive functionalities for managing customers, tariffs, and billing processes associated with charging services. Its open system architecture enables flexible integration with a broad spectrum of hardware devices via secure, encrypted interfaces. Chargecloud supports connection with charging stations compliant with Open Charge Point Protocol (OCPP) versions 1.5 and 1.6, with ongoing development efforts to implement OCPP 2.0. The platform offers a variety of services, including charge.monitor, charge.billing, charge.app, charge.direct, charge.roaming, and charge.partner, thereby addressing diverse operational requirements within the EV charging ecosystem.
- **Zählerfreunde:** Zählerfreunde is a multifunctional platform dedicated to energy management, offering valuable insights for both private households and commercial entities. To influence user behaviour among residents of BC1, an application is being developed that records relevant data and visualises it for end-users. This application also provides information regarding peak solar power production periods to optimize energy consumption. The overarching objective is to integrate data from digital meters, photovoltaic (PV) systems, and charging point infrastructures, thereby enabling comprehensive measurement, reporting, and verification (MRV) processes and facilitating data transfer to the electric vehicle (EV) platform.

Tools, Machines and Hardware:

- **Solar panel:** Within the business case (BC), solar panels employ photovoltaic (PV) cells to convert sunlight into electrical energy. This process contributes to the generation of renewable energy, thereby supporting the energy needs of the buildings involved in the project.
- **EV wallbox:** The charging station is a compact and efficient wall-mounted device designed for electric vehicles, offering faster and safer charging capabilities compared to standard electrical outlets..
- **Digital meter:** The digital meter "IOmeter" measures and records energy consumption in real-time, enabling better energy management and more accurate billing. BEA provides digital meters for all participants in the project to record the required data. The devices are connected to their electricity meters.

1.2 BC2: Improved self-consumption of DER in Energy Cooperatives

Software

- **Enercoop Energy Efficiency App**: Enercoop is developing a solution to improve self-consumption and energy efficiency for energy communities with PV installations. This approach includes informing members through a mobile app to optimise their participation in the energy community and enhance their energy knowledge. The app is a graphical user interface that displays relevant information and data about the energy consumption and production of an end user or a group of end users. A dashboard allows the users to control and optimise their energy efficiency and flexibility solutions, participate in peer-to-peer trading or demand response programs, or access other services or incentives.
- **Energy Management System:** An Energy Management System (EMS), as implemented within the context of an Energy Community, is a system designed to monitor, manage, and analyse the energy consumption and billing data of end users. Beyond these core functions, the EMS is capable of interfacing with external devices and platforms, thereby facilitating interoperability within broader energy infrastructures. By enabling enhanced tracking and management of energy usage, billing processes, and greenhouse gas (GHG) emissions, the EMS supports the efficient operation and sustainability of energy communities.

Tools, Machines and Hardware

- **PV systems**: Photovoltaic (PV) systems are energy systems that convert sunlight directly into electricity using semiconductor materials. PV systems are widely used for renewable energy generation due to their efficiency, sustainability, and ability to function in various environments. In BC2, six roof PV installations in public buildings, starting with one of them
- **Batteries**: Batteries serve a critical function in BC2 by storing electricity for later use, thereby enhancing energy security and facilitating the integration of renewable energy sources. They contribute to balancing energy supply and demand, improving grid stability, and enabling off-grid energy applications. Within the context of the business case, batteries are expected to store

energy generated from renewable sources (e.g. solar power) for utilization during periods of low generation.

- **Smart Meter**: Within the BC2, smart meters are employed to record electricity consumption within the energy community and automatically transmit this data to both the utility provider and end users. In the specific context of BC2, hourly consumption data from community members will be collected and processed internally by Enercoop, both via the smart meters and through its role as the energy retailer. This approach ensures compliance with the General Data Protection Regulation (GDPR).

1.3 BC3: Energy efficiency and flexibility services through smart heating

Software:

- **domX smartphone app**: The domX smartphone app is a mobile application that allows user to manage all domX products through a single user interface. It includes features, such as heating system information and visualizations, energy consumption/savings calculation, and fault detection alerts.
- **domX cloud service**: The domX cloud service is part of a system that offers smart energy services through cost-effective heating controllers. It involves stakeholders engagement and provides targeted information about the benefits of applying automated heating control solutions. This includes data on heating usage, consumption, flexibility management, heating system faults and service management.

Tools, Machines and Hardware:

- **Heating device:** Equipment designed to increase the temperature of an enclosed space is primarily intended to maintain thermal comfort for its occupants.
- **domX Smart heating controller**: The domX heating controller is a cost-effective and universal retrofit solution designed to enhance energy efficiency and improve energy management in legacy building systems.
- **Wireless room thermostat:** This device allows controlling the heating of your home remotely. It connects to your heating system without the need for wired installation and communicates with a central hub or directly with your smartphone

1.4 BC4: Smart energy management for EV chargers and electricity-based HVAC appliance

Software

- **HIVEN smart home energy management**: The HIVEN smart home management system is an intelligent platform designed to optimize energy consumption in homes. It enables cloud-based connectivity with various smart appliances, including EVs, and offers advanced functionalities such as smart charging solutions and the monitoring of residential heating and cooling systems. Furthermore, it supports energy retailers in acquiring and retaining high-value customers, particularly those with EVs and smart home technologies—by facilitating the integration of smart charging and smart heating solutions.

Tools, Machines and Hardware

- **EV Charger:** Hiven EV chargers are EV chargers produced by Hiven. These chargers are designed to provide efficient, fast, and safe charging for electric vehicles, typically used in residential, commercial, or public locations. Hiven incorporates heating and cooling mechanisms in its products to ensure efficient and safe operation. EV chargers, especially fast chargers, generate heat during operation due to high power flow. To prevent overheating, they typically use a combination of cooling and heating management systems.
- **Home Batteries:** The home batteries are designed to work in conjunction with solar panel systems. These home batteries store energy generated by solar panels during the day and release it when needed, like at night or during a power outage.
- **Solar panels:** Within the BC4, solar panels employ photovoltaic (PV) cells to convert sunlight into electrical energy. This process contributes to the generation of renewable energy, thereby supporting the energy needs of the buildings involved in the project.

1.5 Joint Technologies in all BCs

Energyweb Blockchain Platform: The EnergyWeb Chain is an open-source blockchain platform developed specifically for the energy sector. It is a digital infrastructure initiative aimed at decarbonizing the energy sector. The platform has been originally developed by EnergyWeb that is a nonprofit that accelerates the global energy transition by creating Web3 software solutions. The platform offers a variety of technical interfaces to facilitate the integration of blockchain technology into the energy sector. It also supports enterprise-grade solutions to improve coordination across energy markets, enhancing the potential of clean, distributed energy sources.

2 Technology Readiness of Technologies

In this TEP, the Technology Readiness Levels (TRL) are useful for a common understanding of the technology status, for the risk management, as well as decision-making and replication possibilities of the technologies to be used in future energy efficiency projects. Next to a general overview of technological maturity, the TRL levels for the technologies used in InEExS are identified within this document [1].

The TRL system is a methodical framework that evaluates the development stage of a particular technology, allowing for comparison across different technologies. Originally conceived by NASA in the 1970s to gauge and manage the progression and potential risks of space technology, the TRL concept was further refined in 1995 with comprehensive definitions for each tier. Subsequently, the U.S. Department of Defense adopted the TRL methodology for gauging technological maturity, and since then, it has been utilized by various organisations. To this day, TRLs remain an effective tool for covering the evolution status of emerging technology.

Evaluating the readiness of technology is a process that should occur at multiple stages throughout the development life cycle of a new technology or system. A crucial piece of information needed for determining the technology readiness level is the “Performance Objective,” which refers to a specific target for the performance of the new technology and/or system capability. Additionally, it’s vital to present definitive proof that the TRL has been met, possibly through quantitative evidence gathered from validation, testing and so on. Beyond the performance objective, the “Research and development degree of difficulty” is also critical. This should outline potential challenges in development and anticipated uncertainties. Another key element in applying TRL is having a solid grasp of any remaining risks associated with the new technology or system. To aid in this, an Integrated Technology Index (ITI) for various technologies might be useful, as could a matrix that assesses the risk of technology development.

To conclude, a Technology Readiness Level (TRL) model is a systematic way to assess the maturity and readiness of a technology or innovation. It is commonly used in research, development and engineering field to evaluate the progress of a technology from its initial concepts to its practical implementation. By defining TRL, the technology or system provides a scale or framework to measure the advancement of a technology based on specific criteria. It supports stakeholders understand how close a technology is to being fully operational and market-ready. TRL models typically use a numerical scale from 1 to 9, where each level represents a different stage of development [1].

2.1 Overview of TRL model

In total, there are nine original technology readiness levels, which are defined below:

TRL1: The technology’s basic principles are observed and reported.

TRL1 represents the initial level of development within the maturity model framework. During this phase, fundamental principles are identified and qualitatively confirmed. These observations and reports of fundamental principles are then translated into practical research and development activities. Consequently, scientific research reaches completion at this stage. The process’s basic outline starts to take shape, although experimental evidence or analysis has not been produced yet. The development costs associated with TRL1 can vary significantly and are often distinct, indicating that they differ across various research fields.

TRL2: The technology concept is formulated

At TRL2, the focus is on defining a technological concept or application, along with criteria for its implementation. This stage presumes adherence to fundamental physical laws and the potential to develop practical applications based on these principles. Preliminary experiments and analyses validate the technical design's "proof of concept." However, TRL2 applications remain highly theoretical due to the lack of experimental evidence. Furthermore, cost estimates may vary significantly across different fields.

TRL3: A proof of concept exists for an analytical and experimental function

At TRL3, it is expected to provide analytical and experimental evidence of critical functions and/or characteristics. Active R&D efforts are underway, including analytical studies that place the technology in an appropriate framework. Initial laboratory experiments have been conducted. Both the concept and its implementation have been successfully demonstrated within the confines of lab testing.

TRL4: The components of the technology will be validated in a laboratory environment

At TRL4, the integration of fundamental technological elements is necessary to verify that they will function collectively to achieve the performance levels required for concept validation, either at a component level or on a breadboard. A laboratory-based demonstration project in a controlled setting has been initiated. The technology's implementation shows promising prospects for success. Additionally, empirical measurements have supported the analytical forecasts, and models for economic assessment have been developed. The costs are anticipated to be moderate.

TRL5: Component and/or breadboard validation in a relevant environment

At TRL5, the technology has been successfully validated within a pertinent environment. The fundamental technological components have been combined, allowing comprehensive testing of the overall application's quality and resilience within a simulated setting. For subsequent deployment, the technology will be adapted to pertinent sectors, including health and safety, environmental considerations, and resource availability.

TRL6: System/subsystem model or prototype demonstration in a relevant environment

The component and process have demonstrated industrial viability, enabling their incorporation into the production sequence. Current hardware has undergone modifications and enhancements. The majority of issues identified in earlier stages have been resolved. Risk categorization and economic evaluations have been refined. The anticipated expenses for TRL6 are projected to be substantial.

TRL7: System prototype demonstration in a relevant environment

TRL7 represents a significant advancement, necessitating a live demonstration of a system prototype in the intended environment. This prototype showcase confirmed that the project operates flawlessly at a near-commercial stage. Additionally, the final production and feasibility challenges have been pinpointed, and minor technological issues have been addressed. Risk categorization and economic evaluations have been updated and executed.

TRL8: Actual system completed and “flight qualified” through test and demonstration

TRL8 marks the conclusion of system development for the novel technology. This level encompasses the design, development, testing, and evaluation processes. The system is finalized, and the technology is deemed commercially feasible. All technical challenges have been resolved.

TRL9: Actual system “flight proven” through successful mission operation.

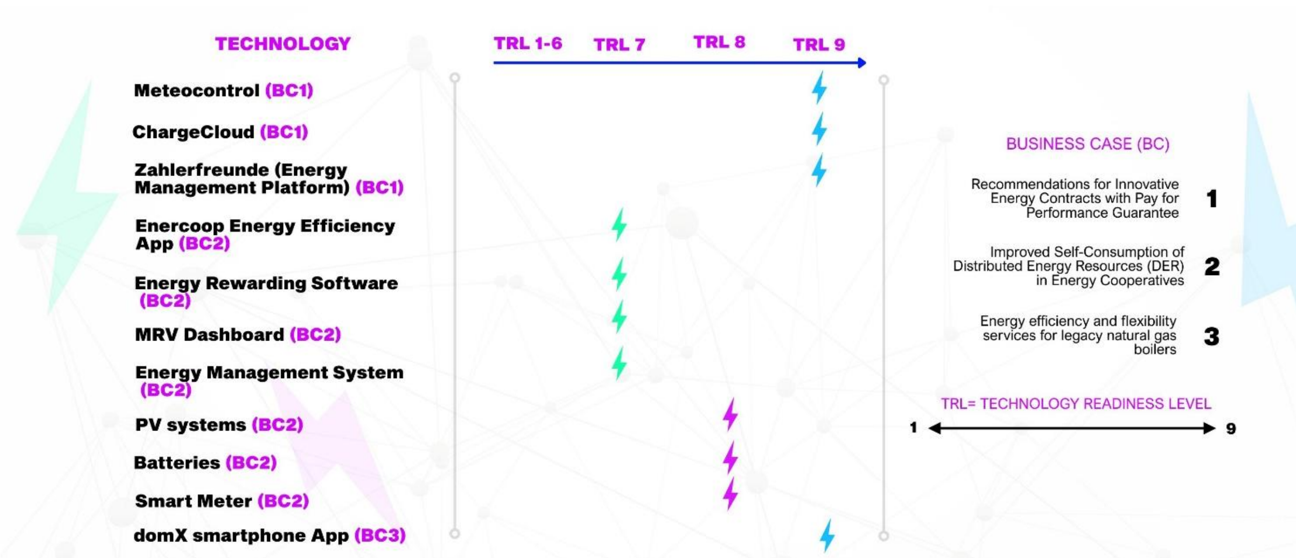
At TRL9, the system is verified and prepared for comprehensive commercial rollout. The entire system has been successfully tested in the relevant environment. The technology is fully developed, and the product is available on the commercial market. The distinct from TRL8 lies in the operational aspect.

2.2 TRL for InEExS technologies

This chapter analyses how the technologies of the BC have been progressed during the project. Hence the chapter aims to identify what technology readiness level has been achieved so far. The development and deployment of advanced technologies plays a critical role in various future industrial and environmental applications.

The development and deployment of advanced technologies play a critical role in various. Throughout the duration of the project, the technologies and services within the BM framework have undergone significant advancements. The following table 1 shows the TRL status of the BCs.

Table 1 TRL assessment of InEExS Technologies



3 Blueprint of the Technologies in the Business Models

A blueprint of technologies in the specific business models refers to the strategic integration of technological advancements into the core operations and offerings of an organisation. This can include the leveraging of different technologies in order to improve efficiency, and create new value propositions. It involves reimagining the role of technology from a support function to a central driver of business innovation and competitive advantage. In this document, a blueprint is a detailed plan or strategy for further development to achieve more technology readiness of services/technologies in the business models. The aim of this chapter is to train the replicants for further use of the technologies. Hence, the section aims at answering how technologies of the business models can be replicated under different technical economic as well as regulatory aspects.

3.1 Replication possibilities

This section involves replication possibilities for each business model, using a feasibility study. This feasibility study includes the four dimensions: technical, economic, legal and operational. In the following, these dimensions are further explained:

Technical dimension: To implement the proposed business models, a range of technologies and equipment will be necessary. The selection of technology will depend on the specific industry and business activities. Likewise, an IT infrastructure will be needed that forms the backbone of modern businesses, supporting various services. Question in this dimension are:

What are the technologies or equipments needed to implement this business model?

What physical or IT infrastructure is needed, such as hardware, software, data storage and networking?

Economic dimension: When considering the replication of business models, the economic dimension is crucial. Common indicators are used to evaluate economic viability include Return on Investment (ROI) and Payback Period (PBP). ROI measures the gain or loss generated on an investment relative to the amount of money invested, while PBP calculates the time required for the return on an investment to repay the total initial investment. Regarding the type of finance or contractual frameworks, different models can be applied depending on this business case. For instance, P4P might be suitable for BC1, where payment is tied directly to the results achieved. In contrast, As a Service (AaS) models could be appropriate for BC2, offering a subscription-based approach.

At the same time, the replication of the technologies requires a specific cost structure that includes all variable and fixed costs associated with its operation. In contrast, the revenue stream defines how the business model will earn income over time. Together, these elements form the financial backbone of any replication strategy. They must be carefully analyzed to ensure long-term sustainability and profitability.

What kind of economic condition exists at each organisation?

What kind of financial incentives exist for measures in the area of energy efficiency or for the participation within energy communities?

How can organisations earn income within the business model?

Legal dimension: When replicating the business models, the GDPR as well as other national regulations should be included in the considerations. Legal aspects are crucial for the replication of business models because they ensure that the replication process respects intellectual property rights, complies with relevant laws and regulations, and considers contractual obligations. This helps to avoid legal disputes and ensures that the replicated business model can operate legally in the new market or context. IPR management,

How is the replication of the business model influenced by GDPR and national regulations?

Operational dimension: Operational aspects are relevant for the replication of business models because they involve the practical execution of the model in a new context. Hence, resources are necessary to ensure business activities. These resources are staffing (required human capital) to identify and secure the right talent with the necessary skills and expertise. Likewise, required skills/expertise, organisational structures and timeline/schedules are necessary.

What kind of operational preconditions exist for replicating the business models?

What kind of difficulties developed through operational aspects?

BC1: Recommendations for innovative energy contracts with Pay 4 Performance guarantee

Dimensions	Replication possibilities in BC1
Technical	Implementation of chargecloud app, meteocontrol, Zählerfreunde app, digital meters, implementation of smart flows.
Economical	Different costs are summarized in the business case: Implementation of the app (10,000 euros), costs of the digital smart meters (80 euros each), costs for the data transfer (1,200 euros).
Legal	The prosumers in the use case have given their consent to the collection of data by the ESCO (BEA).
Operational	The ESCO (BEA) is responsible for the operation of the overall systems. The BC is replicable if different software elements could be combined with each other in a common app. The buildings would also have to be intelligently equipped, e.g. with digital meters, solar panels and EV wallbox.

BC2: Improved self-consumption of DER in Energy Cooperatives

Dimensions	Replication possibilities in BC2
Technical	Enercoop develops its own technical systems (e.g. app) and is responsible for the running of the Energy Efficiency App and Energy Rewarding Software. The software is in use and it is in a mature status.
Economical	BC2 involves 10 Energy Communities and 1200 households. However, the time dedicated to administrative process is long and the risk develops of a lack of understanding or capacity of workers to develop a project. For the replication, approximately one year is needed to constitute the energy

	community, as well as one year to design and develop the PV projects and start energy sharing. The financial feasibility is done by payback period (PBP), calculation of revenue streams by variable costs, cost savings and pricing strategy
Legal	The regulation of energy communities' self-consumption installations is under continuous regulatory modifications. At a national level, the royal decree-law 15/2018 introduced certain modifications about Law 24/2013, of the Energy Sector, to be aligned with Directive 2018/2001 and now recognizes the right to self-consume energy without penalties. The prosumers in the use case have given their consent to be part of the energy communities and the usage of their data.
Operational	Enercoop is responsible for the operation of the systems in the energy community. The BC can be replicated in larger energy communities that can be connected to a larger PV park. The technologies used could also be utilised in other similar business cases.

BC3: Energy efficiency and flexibility services through smart heating

Dimensions	**Replication possibilities in BC3**
Technical	The technologies used in BC3 are a mature technical system. domX is responsible for the further development and running of the technical systems.
Economical	The expected economic result and impact for initial and follow-up three years is described in business model (BC3) of Deliverable 2.1. The economical aim is the reduction of energy bills with additional incentives by tokens.
Legal	domX works within the legal national and international framework.
Operational	domX is responsible for the operation of the systems. In coordination with domX, the technologies can also be used in other contexts that are familiar with flexibility services through smart heating.

BC4: Smart energy management for EV chargers and electricity based HVAC appliances

Dimensions	**Replication possibilities in BC4**
Technical	Hiven is responsible for the systems in the BC4; the technical feasibility of the software and hardware is given; qualified system with proof of functionality in the area of application
Economical	Hiven is a B2B provider of smart energy as a service to businesses with strong B2C base (B2B2C SAAS). There are competitors operating B2B and building competing B2C offering directly (Octopus, Synergi, Tibber, Gridio, EV energy) in the same segment. High market relevance as EV's in Europe 2035 ~130M; Households in Europe 260M; Households in the Nordics ~10M; domestic smart energy appliance >65GW
Legal	The business case works within a legally regulated national and international framework.
Operational	Hiven is responsible for the operation of the system. Hiven therefore provides the services to other companies, as B2B refers to transactions or

	interactions between two businesses, rather than between a business and individual consumers.

4 Smart Grid Architecture Model

The Smart Grid Architecture Model (SGAM) is a comprehensive framework for the standardised description of system architectures for smart grids. SGAM is an architecture framework, which integrates aspects of ICT, technical and business functions that should organise components, relationships as well as principles to establish functionality of the smart grid [2].

4.1 Overview of the Smart Grid Architecture Model

The SGAM was developed as part of the European mandate M/490 by the Smart Grid Coordination Group, which is supported by the European Committee for Electrotechnical Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI). The SGAM aims to identify gaps in smart grid standardisation and is currently used as a reference and architecture model. Overall, the framework has a high level of acceptance, particularly in the energy domain, and is increasingly being used in the deployment of smart grid system architectures in the European Union. SGAM plays a crucial role in managing the complexities of integrating innovative use cases, such as including distributed renewable energy sources while enhancing grid resilience against potential cyber threats [3].

In this deliverable, the SGAM serves as a common approach to combine technical and organisational aspects of the business models. It includes business and technical representation of technologies in the use cases in a common visual representation. The SGAM consists of an SGAM Plane as well as five interoperability levels. The SGAM Plane is divided into different domains, namely bulk generation, transmission, distribution, distributed energy resource. The zones in SGAM represent the hierarchical levels of power system management, from physical infrastructure to business processes [3].

SGAM Zones:

- **Process Zone:** Includes physical equipment like generators, transformers, and circuit breakers.
- **Field Zone:** Comprises sensors, actuators, and protection devices that interact with the physical grid.
- **Station Zone**: Encompasses substations and local control systems managing data and grid conditions.
- **Operation Zone**: Covers control centers responsible for grid operation, such as SCADA and EMS (Energy Management Systems).
- **Enterprise Zone:** Involves utility-level business processes like billing, asset management, and planning.
- **Market Zone**: Represents electricity markets, trading platforms, and demand-side participation.

SGAM Domains: **The domains classify the different functional areas of the energy system, from power generation to consumption.**

- **Generation:** Covers all forms of power generation (conventional, renewable, distributed).
- **Transmission:** Manages the high-voltage transport of electricity over long distances.
- **Distribution:** Handles the medium- and low-voltage distribution of electricity to consumers.
- **DER (Distributed Energy Resources):** Encompasses small-scale generation, storage, and active consumer participation.
- **Customer Premises:** Includes residential, commercial, and industrial energy users with smart devices, demand response, and prosumers.

Interoperability layers:

- **Business Layer:** Defines the high-level goals, policies, and regulatory requirements of smart grid operations.
- **Function Layer:** Represents smart grid functionalities, use cases, and services.
- **Information Layer:** Specifies the data models and information exchanges between different systems.
- **Communication Layer:** Details the protocols and technologies used for data transmission.
- **Component Layer:** Consists of physical devices like sensors, control systems, and energy storage.

4.2 SGAM for each BC in InEExS

BC1: Recommendations for innovative energy contracts with Pay4Performance guarantee

BC1 deals with sector coupling in the energy sector using a building complex in which solar power is produced on the roof. This can then be used in the underground garage to charge electric vehicles or in the residential units themselves. Currently, only 60-70% of the electricity produced is used directly. The remaining solar power must therefore be fed into the grid. In that frame, the aim of InEExS is to increase the utilization of solar power to its maximum in the best-case scenario. To change the user behaviour of the residents, an app is to be used that records important data and visualizes it for the app users. The app also provide information when solar power is at peak production and should be used. BC1 aims to encourage a change in behaviour among the building's residents by suggesting ways to optimize the use of solar power. The app will document how the utilization of solar power changes over the course of a year. BC1 will use the results to derive the extent to which flexible electricity tariffs can also financially reward the use of solar power in the future.

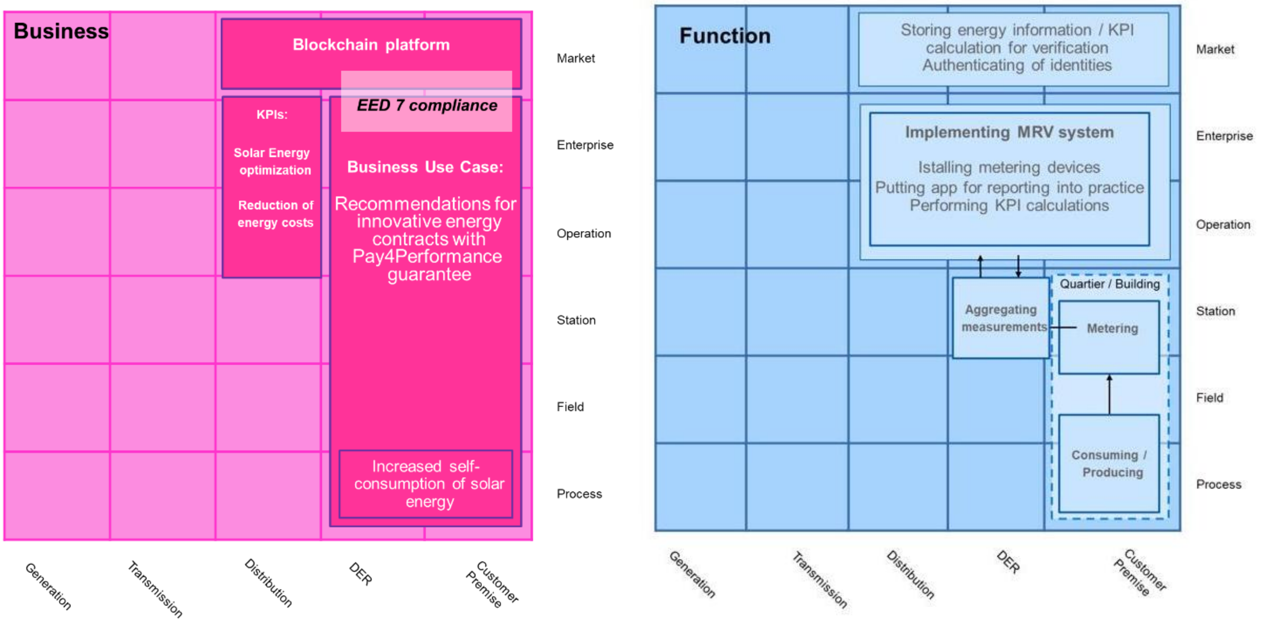


Figure 1 BC1 Business and Function Layer

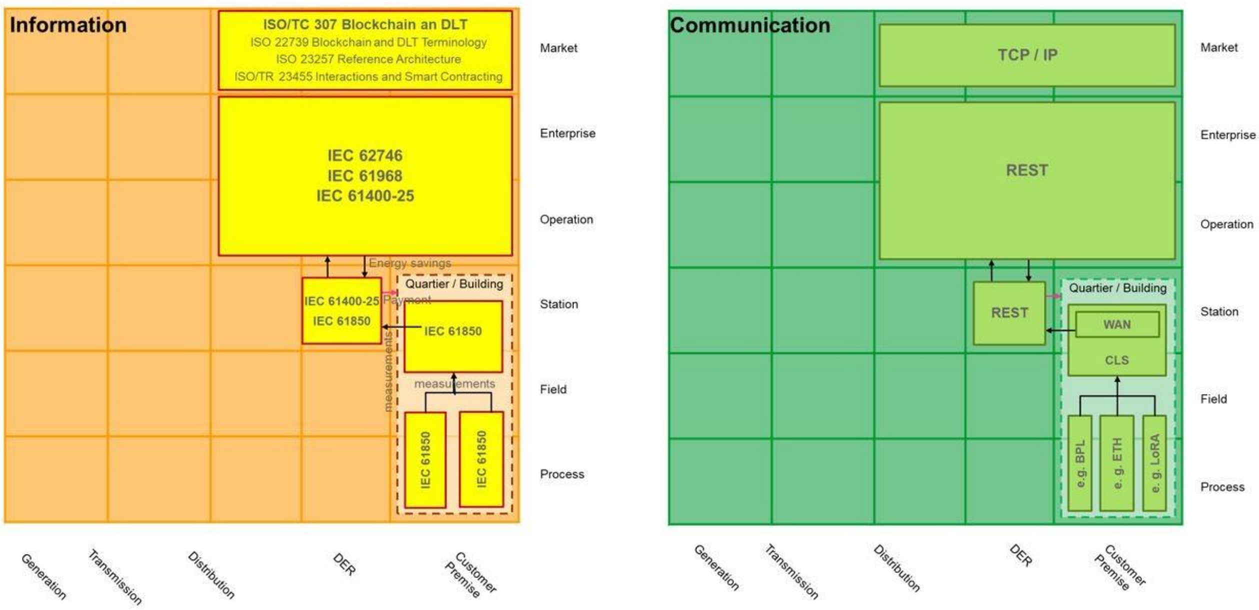


Figure 2 BC1 Information and Communication Layer

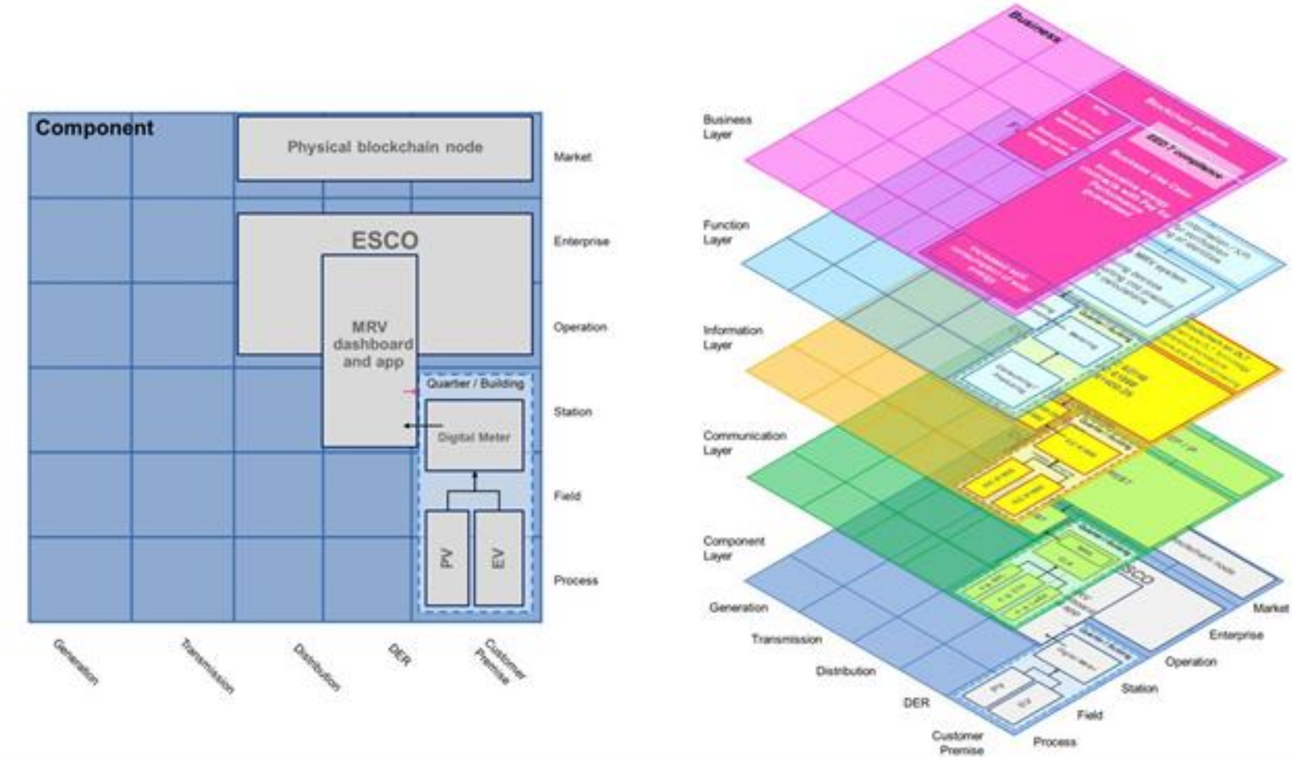


Figure 3 BC1 Component Layer and SGAM

BC2: Improved self-consumption of DER in Energy Cooperatives

This BC2 aims to empower residential households to become active energy consumers, or prosumers, who can produce and consume their own renewable electricity. By joining energy cooperatives, prosumers can benefit from shared resources, lower costs, and better services. The BC2 also seeks to improve the self-consumption of distributed energy resources (DER), such as solar panels and batteries, by using smart technologies and innovative solutions. This can help prosumers reduce their bills, increase their energy security, and support the integration of renewable energy sources into the grid. The BC2 contributes to the EU's renewable energy targets and the energy transition.

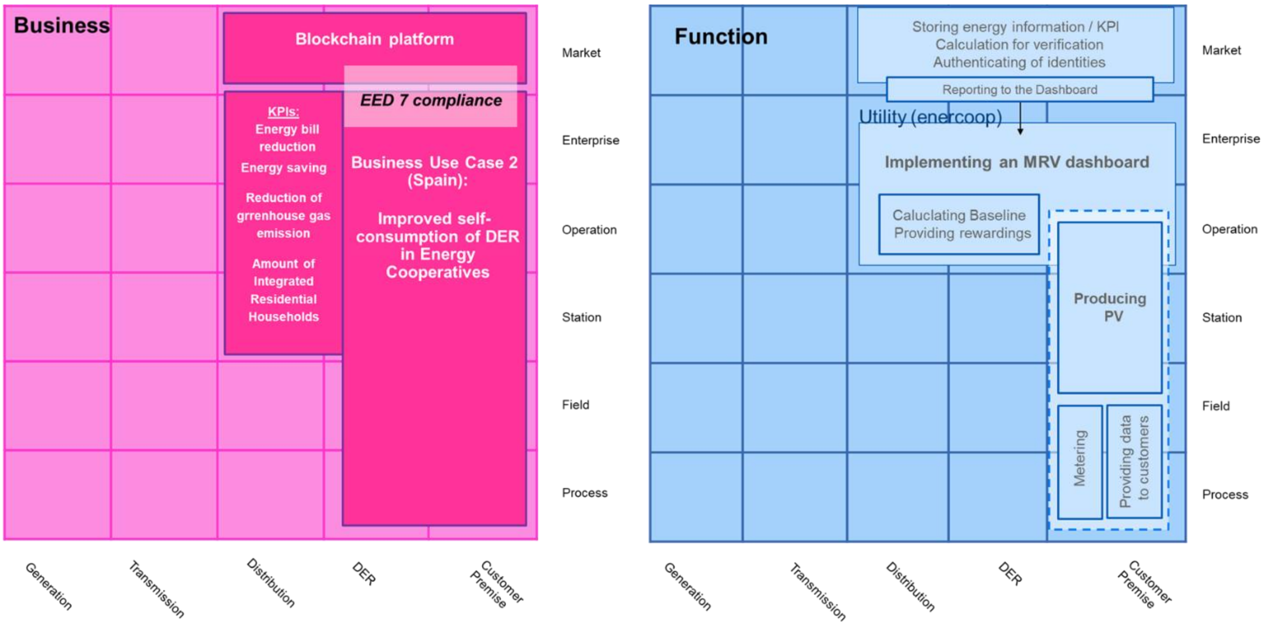


Figure 4 BC2 Business and Function Layer

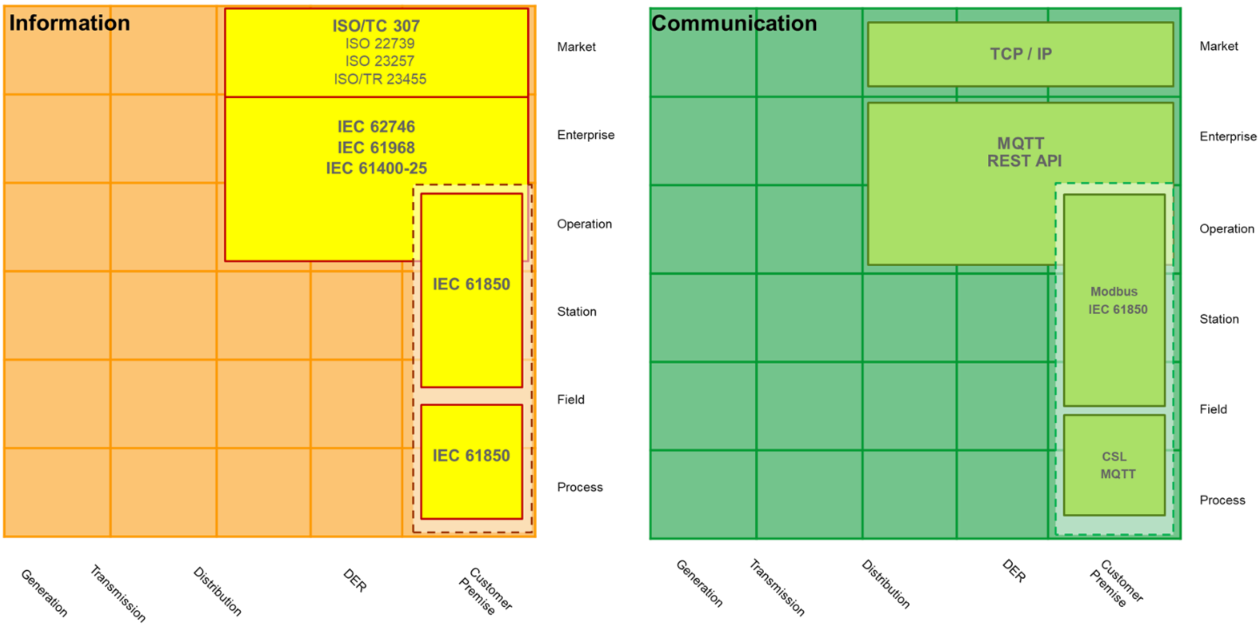


Figure 5 BC2 Information and Component Layer

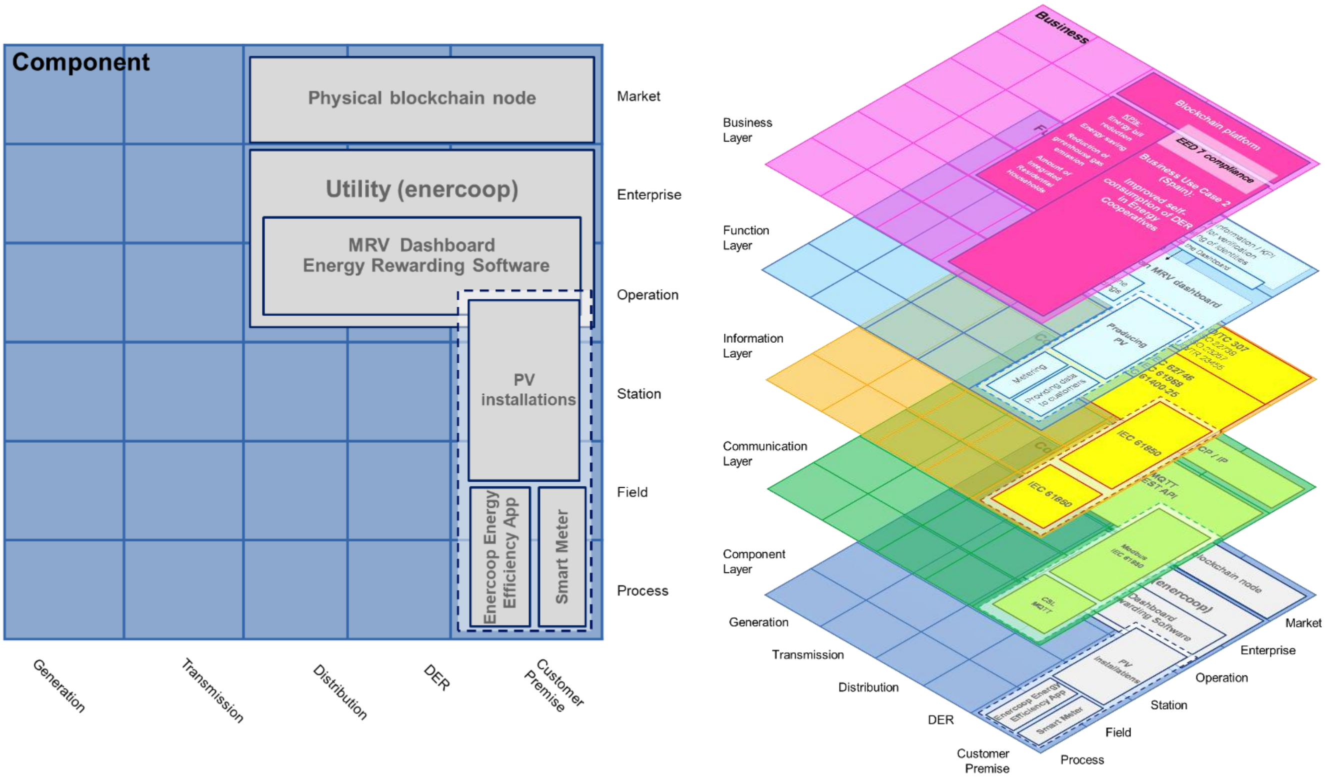


Figure 6 BC2 Component layer and SGAM

BC3: Energy efficiency and flexibility services through smart heating

BC3 focuses on the management of space heating consumption in households, by actively controlling and optimizing the indoor environment with the aim of (a) improving their energy efficiency through load reduction, while respecting their comfort limits (b) evaluating the achieved energy savings at the residential consumer portfolio level, c) contributing to the energy efficiency obligations of the energy supplier.

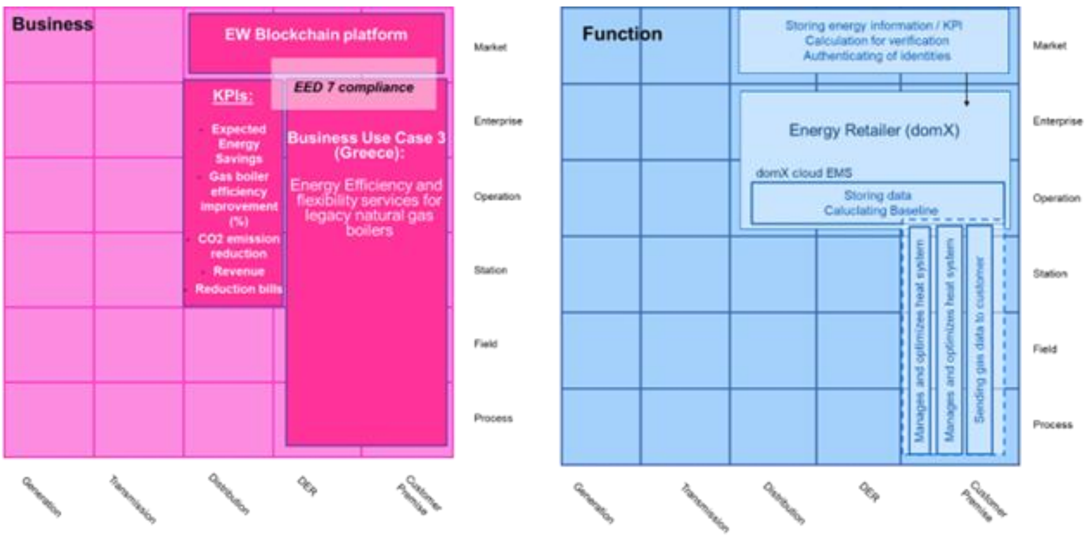


Figure 7 BC3 Business and Function Layer

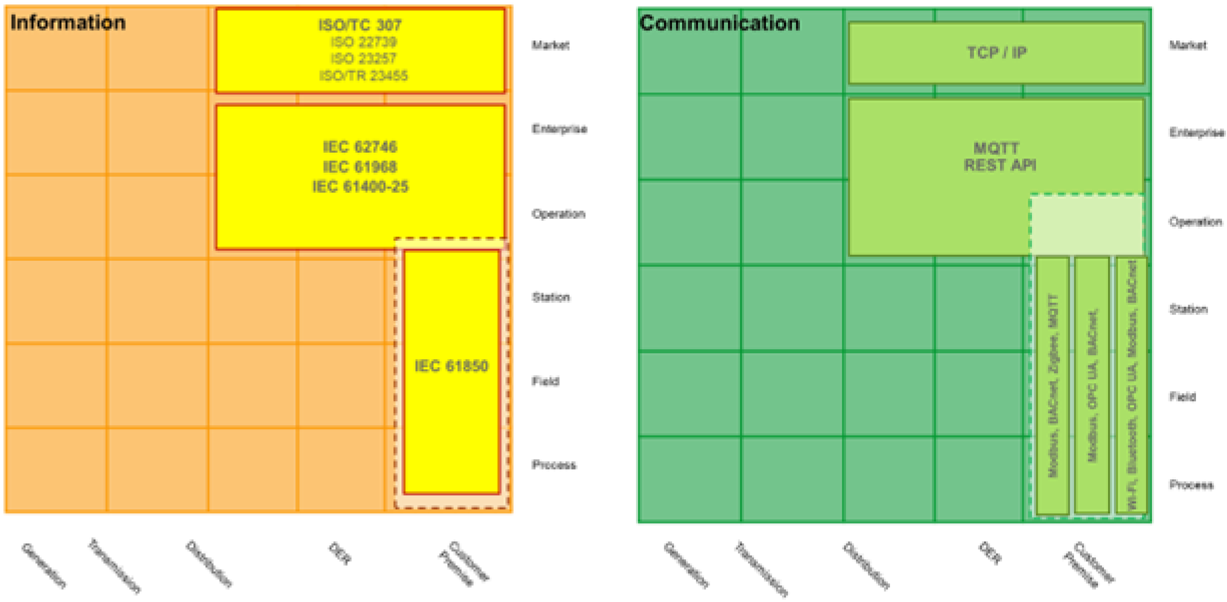


Figure 8 BC3 Information and Communication Layer

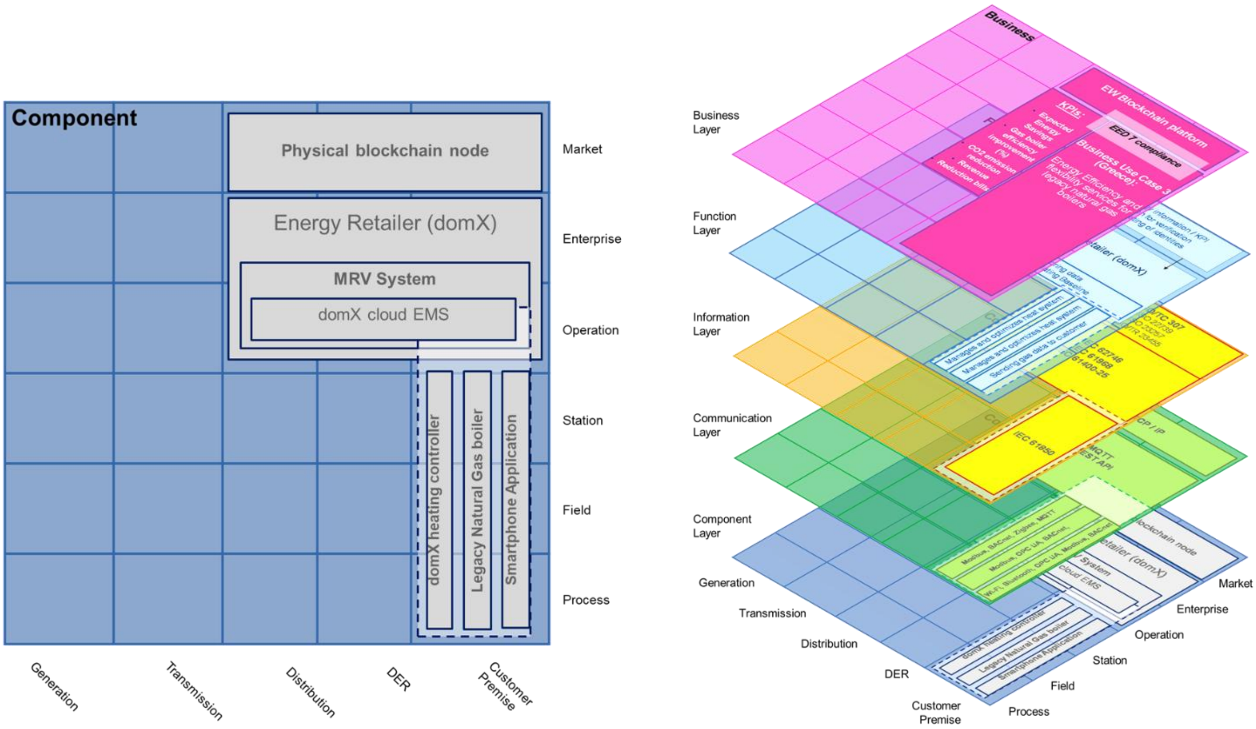
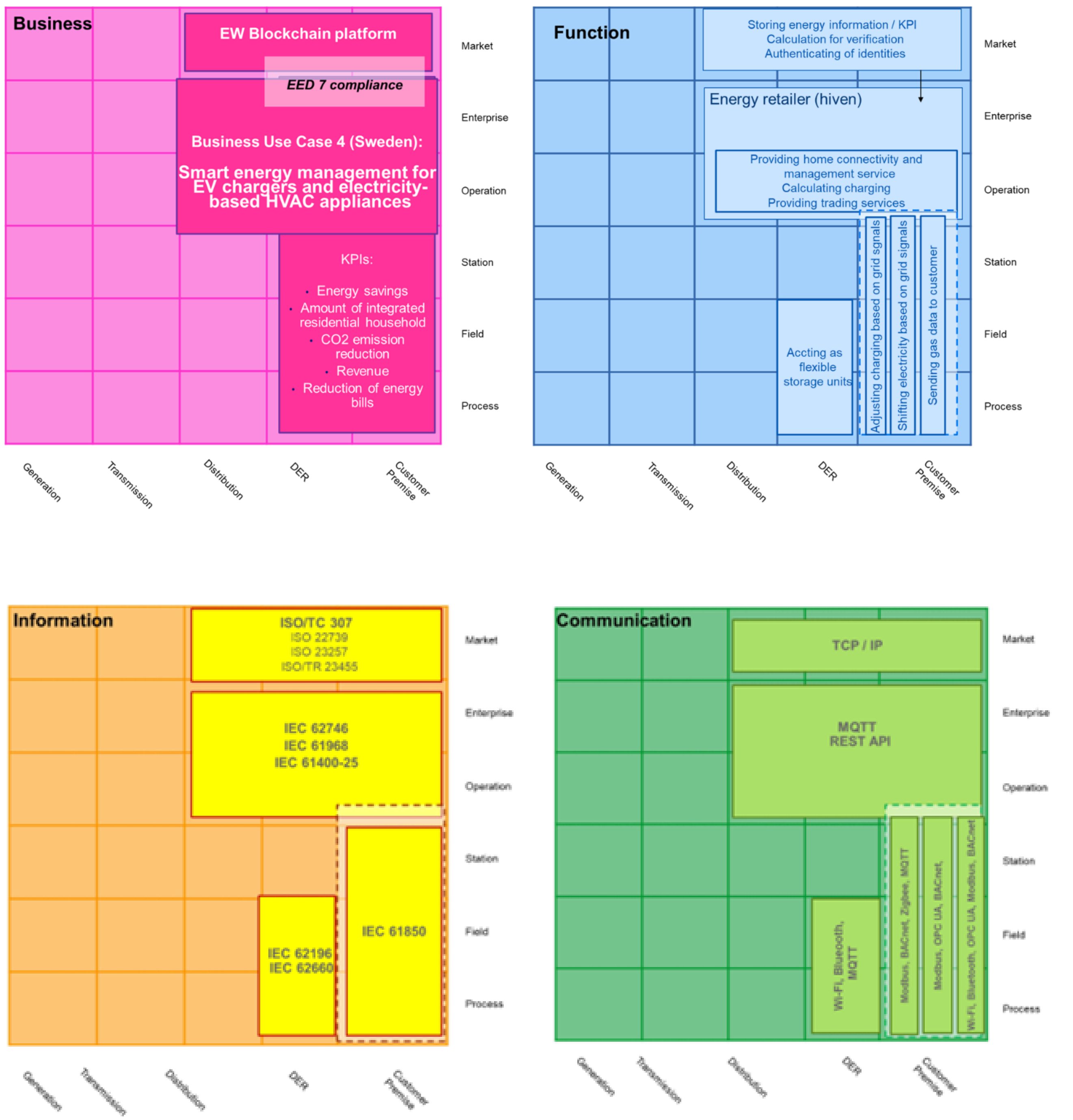
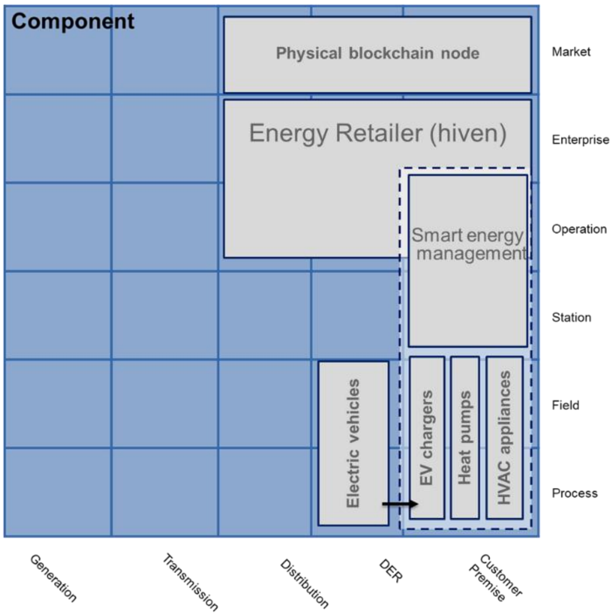


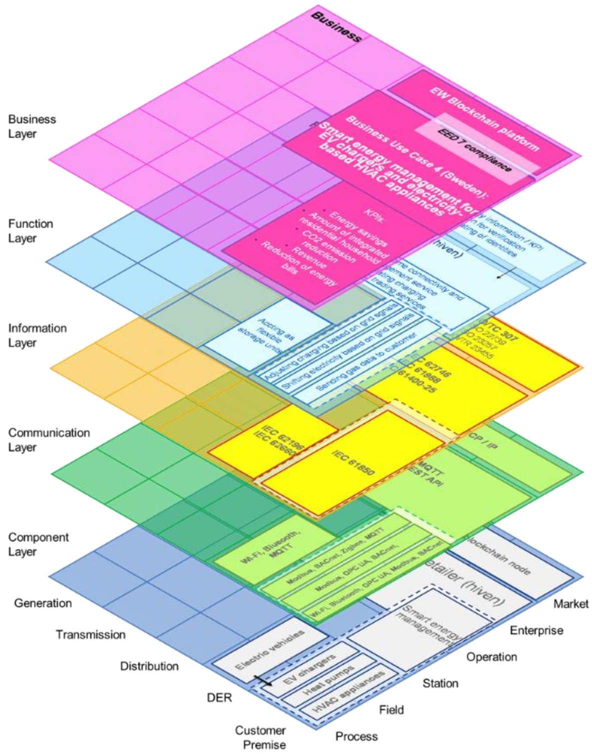
Figure 9 BC3 Component layer and SGAM

BC4: Smart energy management for EV chargers and electricity-based HVAC appliances

BC4 is about the development of a smart energy management for EV chargers and electricity-based HVAC appliances. This smart energy management is a system that optimizes the existing charging infrastructure for electric vehicles by using different technical solutions. The system can be used to manage the charging of electric vehicles in a way that minimizes the impact on the grid and reduces the cost of charging.




Component
Physical blockchain node
Energy Retailer (hiven)
Smart energy management
Electric vehicles
EV chargers
Heat pumps
HVAC appliances
Market
Enterprise
Operation
Station
Field
Process
Generation
Transmission
Distribution
DER
Customer Premise


Business
Business Layer
Function Layer
Information Layer
Communication Layer
Component Layer
EW Blockchain platform
Business Use Case 4 (Sweden):
Smart energy management for EV chargers and electricity-based HVAC appliances
IEC 61850
Generation
Transmission
Distribution
DER
Customer Premise
Process
Field
Station
Operation
Enterprise
Market

5 Conclusion

The TEP has provided a comprehensive analysis of the technology experiences within the context of the EU project, focusing on the interplay between business models, technological readiness, replication potential, and smart grid architecture.

Through the four distinct business models, we explored how innovative value propositions can drive the adoption of smart grid solutions, considering economic, regulatory, and operational factors. Each model presents unique opportunities for stakeholders, demonstrating the diverse pathways toward energy transition and grid modernization.

The TRL assessment highlighted the maturity of key smart grid and energy technologies, offering valuable insights into their current deployment status and the challenges associated with their scalability. By mapping TRLs across the different business models, we identified critical gaps and potential areas for further development to accelerate market adoption.

A crucial aspect of this analysis was the replication potential, where we assessed the feasibility of scaling these solutions across different EU regions. Factors such as regulatory alignment, infrastructure compatibility, and stakeholder engagement play a vital role in ensuring the successful replication of proven smart grid innovations. The findings indicate that while some business models are readily transferable, others require localized adaptations to address specific market conditions.

Finally, the Smart Grid Architecture Model (SGAM) mapping for each business model provided a structured framework to understand the technical, functional, and communication layers of the proposed solutions. This systematic approach ensures interoperability, integration with existing grid infrastructures, and alignment with EU energy policies and digitalization strategies.

In summary, the insights gained from this report reinforce the importance of aligning business models with technology readiness and replication strategies to foster the large-scale deployment of smart grid solutions. The findings contribute to the broader EU objectives of sustainability, resilience, and digital transformation within the energy sector. Moving forward, continuous collaboration between policymakers, industry players, and technology providers will be essential to overcome barriers and unlock the full potential of smart energy innovations across Europe.

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