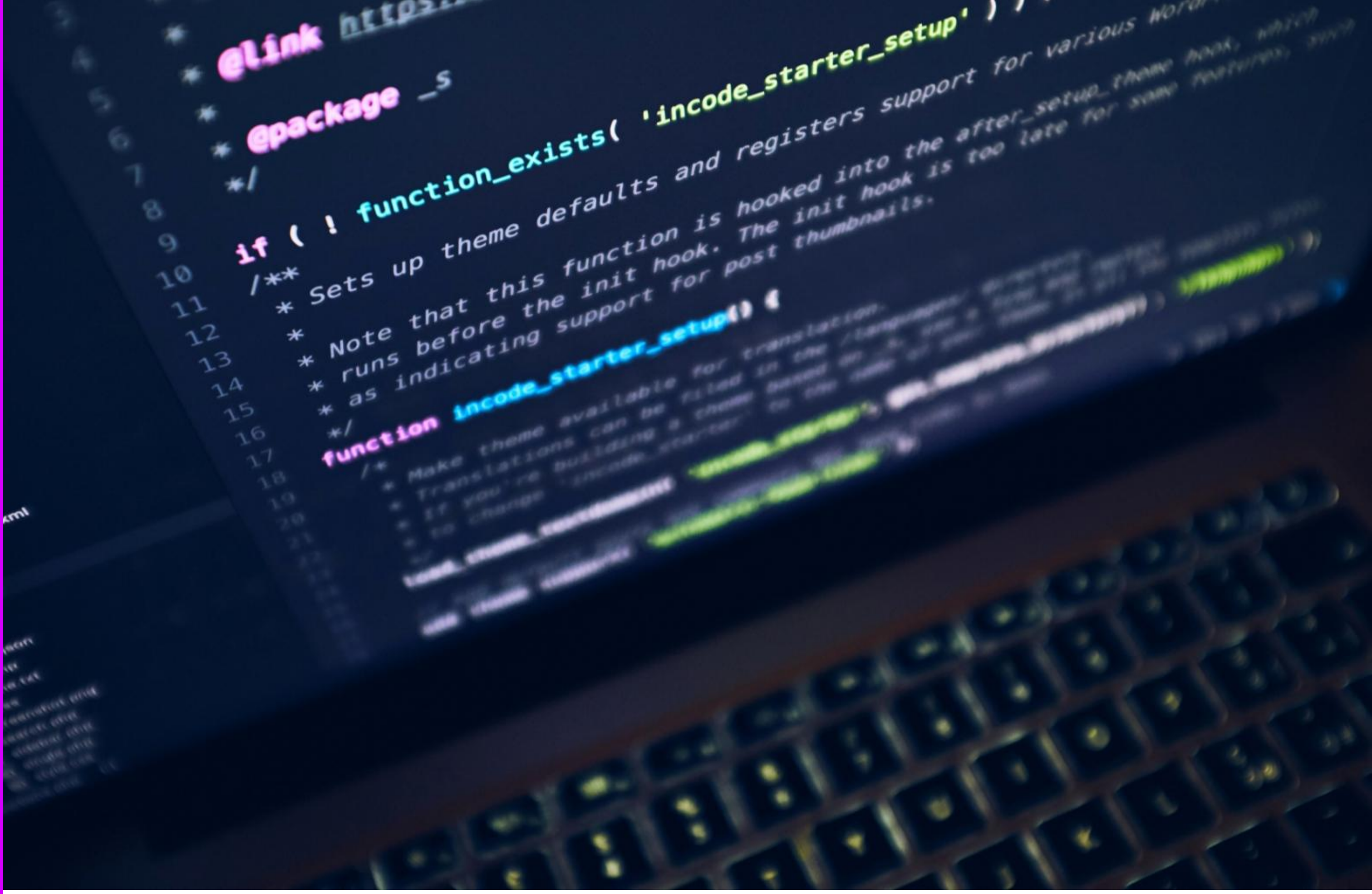

InEExS
ENERGY SERVICES ON THE BLOCKCHAIN

Business and Policy Roadmaps

D4.2

Co-funded by the European Union under project ID 101077033. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Project Acronym	InEExS
Project Name	Innovative Energy (Efficiency) Service Models for Sector Integration via Blockchain
Project Coordinator	IEECP
Project Duration	01/11/2022 – 31/10/2025
Website	https://ieecp.org/projects/ineexs/

Deliverable No.	D4.2
Dissemination Level	Public
Work Package	4
Lead beneficiary	IEECP
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Date	30/12/2024
File Name	D4.2 Business and Policy Roadmaps

Published in 30/12/2024 by InEExS.

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GLOSSARY

AI	Artificial Intelligence
API	Application Programming Interface
B2B2C	Business-to-Business-to-Customer
B2C	Business-to-Customer
BACS	Building Automation and Control System
BAS	Building Automation System
BC	Business Case
BEMS	Building Energy Management System
BRP	Balance Responsible Party
CEN	European Standardization Organization
CPP	critical peak pricing
DE	Germany (Deutschland)
DEEPP	Decentralised Energy Efficiency Power Plant
DEMS	District Energy Management System
DER	Distributed Energy Resources
DLT	Distributed Ledger Technology
DRP	Demand Response Program
EaaS	Energy-as-a-service
EE	Energy Efficiency
EED	Energy Efficiency Directive
EEO(S)	Energy Efficiency Obligation (Scheme)
EMS	Energy Management System
EPBD	Energy Performance Building Directive
ES	Spain (Espana)
ESA	Energy Savings Agreements
ESC	Energy Service Contract
ESCO	Energy Service Company
EU	European Union
EV	Electric Vehicle
FMS	Facility Management Systems
FR	France
GDPR	General Data Protection Regulation
GR	Greece

HEMS	Home Energy Management System
HVAC	Heating, ventilation, and air conditioning
ICT	Information and communication technology
IoT	Internet of Things
IRES	Integrated Renewable Energy Sources
IT	Italy
ML	Machine learning
M&V	Measurement & Verification
MRV	Measurement, Reporting, Verification
MS	Member State
NECPs	National Energy and Climate Plans
nZEB	Nearly Zero-Energy Building
PV	Photovoltaics
P2P	Peer-to-Peer
P4P	Pay-for-Performance
PPA	Power Purchase Agreement
ROI	Return of Investment
RTP	real-time pricing
SG	Smart Grid
SLA	Service Level Agreement
SM	Smart Meter
SRI	Smart Readiness Indicator
ToU	Time-of-Use
V2G	Vehicle-to-grid
VPP	Virtual Power Plant

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1 Executive summary

This InEExS Business and Policy Roadmaps report serves as a complementary guide to identifying and addressing barriers for integrating innovative energy efficiency services and technologies across sectors, facilitated by Distributed Ledger Technology (DLT). The aim of this report is twofold: **to assess and overcome the regulatory, financial, and market design barriers** at the EU and Member State levels that could hinder smart service and technologies implementation, and **to identify and prioritise viable smart services and technologies** that can connect energy sectors and carriers, promoting greater energy efficiency and flexibility.

Objectives and Scope:

The InEExS project is supportive of the EU's climate and energy goals, aiming to accelerate the adoption of smart services and technologies that enable energy efficiency, optimise resource use, and integrate renewable energy. Specifically, this document outlines a roadmap to address barriers within five distinct Business Cases (BCs), each representing various energy service and technology applications, from residential heating optimisation to future-looking decentralised energy efficiency power plants. Each BC applies tailored solutions to its context, such as energy cooperatives, smart home appliances, and legacy heating systems, with a particular focus on overcoming barriers through regulatory alignment, financial support, and market engagement. The document identifies 18 specific key barriers hindering the successful integration of energy services and technologies, ranging from regulatory to market and financial issues. The primary objective is to provide a comprehensive understanding of this barriers and propose strategies, through developed BCs, to address them.

Additionally, the document includes the analysis of the prioritization of viable smart services and technologies based on the feedback gathered from an online survey. The survey, distributed among InEExS project partners, provided valuable insights into the most feasible and usable energy services and technologies and their relative importance in energy sector.

Barriers in regulation, finance, and market design

Regulatory barriers in energy systems hinder the integration of renewables, data sharing, and consumer participation. Key issues include lack of or unclear regulations related to energy efficiency and integration of smart services and technologies, unclear data privacy rules, limited support for energy communities, and insufficient transition policies for natural gas systems.

Financial barriers in energy systems impede the deployment of renewables, energy efficiency projects, and demand-side flexibility. Key challenges include limited access to funding, high upfront costs, lack of standardized financial models and incentives, and risk aversion among financial institutions. Many households and enterprises are not offered financial support for smart service and technology implementation due to the absence of structured incentives or public funding mechanisms.

Market barriers in energy systems slow innovation and adoption of smart services and technologies. Key challenges include the lack of blockchain case studies in the EU which impedes the scalability and integration of technologies into energy market. Moreover, limited mechanisms for aggregated offers and bids, insufficient market access for smart technologies and fragmented energy trading rules negatively effect on the commercialization of technologies, while and low consumer awareness and participation impedes their implementation and adoption due to unfamiliarity with the technology's benefits.

Identification and prioritisation of smart services and technologies

The report identifies various smart services and technologies crucial to supporting energy efficiency goals, including services based on smart metering, demand response programs, and blockchain-based energy trading. Through a prioritisation matrix, these services and technologies are ranked based on criteria such as sustainability, ROI, scalability, and cross-sector compatibility. High-priority services and technologies, such as Integrated Renewable Energy Systems and Smart Grids, are recommended for immediate focus due to their high impact on flexibility services.

Smart service and technology applications across business cases

Each Business Case within the InEExS project demonstrates a unique application of smart services and technologies in achieving energy efficiency. Examples include:

- Innovative energy contracts with Pay for Performance guarantees (BC1): Implementing dynamic tariffs and self-consumption optimisation for residential solar PV systems.
- Improved self-consumption of Distributed Energy Resources in Energy Cooperatives (BC2): Enhancing DER self-consumption for energy cooperatives using tokenisation and incentive mechanisms.
- Decentralised Energy Efficiency Power Plant/ DEEPP (BC5): Integrating diverse energy-efficient technologies within a Virtual Power Plant (VPP) model, which aggregates demand-side assets and energy efficiency projects under one financial structure.

Recommendations

To address barriers and support the widespread adoption of smart energy services and technologies, the report offers the following recommendations:

1. **Standardize grid integration frameworks** by developing a national framework to simplify the integration of renewables and DERs into the grid. This includes establishing uniform rules for feed-in tariffs and creating clear guidelines for peer-to-peer (P2P) energy trading to streamline processes, reduce administrative challenges, and encourage greater participation in renewable energy initiatives.
2. **Providing consistent support for energy communities** in a way that energy communities are legally recognisable and have access to administrative and financial support. Simplified registration processes, grants, and subsidies for community-led renewable projects will empower local communities to actively contribute to decentralized energy systems while fostering inclusivity and engagement.
3. **Balancing natural gas transition policies** by incorporating interim support for improving natural gas systems during the transition to renewable energy. Measures such as retrofitting infrastructure and promoting hybrid systems that combine natural gas with renewables will maintain system reliability while reducing emissions.

4. **Creation of National Green Energy Funds** to finance renewable energy projects, energy efficiency initiatives, and innovation in sustainable technologies. By pooling contributions from public, private, and international stakeholders, these funds will make financing accessible for diverse projects, driving the energy transition at a national level.
5. **Standardization of renewable energy incentives** by harmonizing feed-in tariffs, renewable energy purchase agreements (REPAs), and other incentives at the national level. Standardization will reduce uncertainty, attract investors, and create uniform conditions for expanding renewable infrastructure.
6. **Simplification of the access to state and public funds** by streamlining applications for national and EU funding to reduce administrative burdens. Clearer requirements and technical assistance will enable smaller entities and local communities to benefit from available financial resources.
7. **Development of national pilot programs for blockchain applications** through launching pilot projects at the national level to explore blockchain's potential in energy trading, P2P transactions, and demand-side management. These programs will test innovative applications, provide insights, and build stakeholder confidence in blockchain solutions for energy markets
8. **Running the awareness campaign for consumers** by educating consumers on energy market opportunities, including dynamic pricing, demand response programs, and P2P trading. Digital platforms, community events, and financial incentives can be used to increase consumer engagement and drive the adoption of smart energy solutions.

The integration of smart services and technologies into the energy sector represents a significant opportunity for achieving an efficient, integrated and responsive energy system. Its success depends on addressing the regulatory, financial, and social barriers that may restrict progress depending on locality. This roadmap is set up to support stakeholders across sectors—policymakers, businesses, and end-users—to realise the benefits of smart services and technologies, thereby advancing the energy transition towards the EU’s 2030 and 2050 targets.

2 Structure of the document

The document is organised into six sections, each designed to guide the reader through the complex landscape of integrating innovative energy efficiency services and technologies and overcoming associated challenges.

A detailed **introduction** outlines the current state of the market for smart services and technologies, identifies prevalent challenges, and defines the scope and purpose of the report within the InEExS project framework.

The **policy background** section examines the regulatory and market contexts underpinning the development of smart services and technologies. Drawing on a thorough review of European Union regulations and relevant literature, this section establishes the foundational policies that support the implementation of innovative energy efficiency services and technologies while highlighting the barriers that must be addressed.

An **overview of smart services and technologies and Business Cases** is provided next, offering insights into the specific applications of smart services and technologies across the five Business Cases (BCs) developed under the InEExS project. This section identifies the technologies and strategies employed, the stakeholders involved, and the contexts in which these services are implemented or planned.

The **roadmap for overcoming barriers in regulation, finance, and market design** addresses the challenges identified in the previous sections. It provides an analysis of the factors impeding the adoption of smart services and technologies at both the Member State and EU levels, coupled with actionable recommendations for addressing these barriers through regulatory alignment, financial mechanisms, and market engagement.

Following this, **the roadmap on the identification and prioritisation of viable smart services and technologies** focuses on connecting energy sectors and carriers. It details the methodology for prioritising smart services and technologies based on sustainability, scalability, and cross-sector impact, offering guidance on which services and technologies should be emphasised to maximise energy efficiency and sustainability outcomes.

The report concludes with a synthesis of the findings and actionable next steps. This section summarises the critical insights from the preceding sections and outlines recommendations for further research, implementation strategies, and policy development.

3 Introduction

The energy sector is one area where smart services and technologies play an increasingly important role. Hitherto, research on so-called smart energy services and technologies is scarce, but the research on the development of smart services and energy services is partially transferable, e.g., general structure and overarching value proposition [1]. Many factors continuously impact how services and products are designed and developed. The form of innovative solutions is, on the one hand, determined by market demands and needs. However, technological advancements set new boundaries for actual reality and the boundaries of practical application [2]. Current trends, like dispersed component-based apps, cloud storage that is both remote and distributed and ubiquitous access, directly influence how the service is realised and set user expectations. Artificial intelligence (AI) techniques, data analytics, and data availability and quantity, including big-data approaches, have all had a significant impact on the development of smart services and technologies, helping to define their specific attributes [2]. Moreover, equally important is a favourable environment that fosters the acceptance of novel solutions.

On the trail of it, for easier and smoother energy transition, it is crucial to investigate the digitalisation of energy services and technologies through the integration of cutting-edge technologies and tools [3]. The introduction of blockchain technology has provided a new set of opportunities in the energy sector and it could help meeting goals, like energy efficiency and energy transition, since applications such as emission trading systems, Peer-to-peer (P2P) energy trading in smart grids, energy management in systems with high contribution of renewable sources in energy production can be supported by blockchain-based models [4].

The decentralised nature of blockchain, combined with the security, transparency and safety it provides, make it a very promising technology for energy management and trading implementations, among others. Smart grids, microgrids, energy trading, storage, energy management, electric cars, carbon reduction, and smart meters are some of the energy-related application domains for blockchain technology. However, technical constraints, such as the scalability problem, security threats, as well as sociopolitical and regulatory barriers should not be neglected [5].

The InEExS project (*Innovative Energy Efficiency Service Models for Sector Integration via Blockchain*) is an EU funded LIFE programme project based on the potential to leverage the knowledge and experience already in place to help introduce smart services and technologies to legacy energy actors to support their future digitalisation and decentralisation [4].

Therefore, the purpose of this document is:

1) Identification of the regulatory, finance, and market design barriers that can hinder the implementation of business cases at Member States (MS) and EU levels with the purpose of proactive interventions that can minimise the aforementioned risks
2) Identification and prioritisation of viable smart services and technologies that can serve as a connection between energy carriers and business sector to enhance the wide application of energy efficiency measures and the use of renewable and distributed energy
3) Inclusive approach of the actors in the wider stakeholder arena that can benefit from the new business cases proposed by InEExS.

4 Policy background

Buildings account for 40% of total energy consumption and 36% of energy-related greenhouse gas emissions in the European Union (EU); however, the weighted annual energy renovation rate at the EU level is only about 1% (Impact Assessment for the Energy Performance of Buildings Directive, EPBD). Moreover, even though the implementation of clean energy regulations has advanced significantly, the energy sector still mostly relies on fossil fuels. Thus, decarbonisation of the building sector is essential to achieving the EU's 2030 and 2050 climate and energy objectives [6].

To address these issues and for promoting the clean energy transition, the EU is acting decisively. In December 2019, the European Commission presented the EU Green Deal which aims to reduce EU GHG emissions by 55% by 2030 and to achieve carbon neutrality by 2050 (fit-for-55 package). The European Green Deal sets three key principles for ensuring a secure and affordable EU energy supply; developing a fully integrated, interconnected and digitalized EU energy market; and prioritising energy efficiency, improving the energy performance of buildings and developing a power sector based largely on renewable sources [7]. Furthermore, in May 2022, the EU presented REPowerEU, a plan to phase out Europe’s dependency on Russian energy imports. It also puts forward a set of actions to save energy, diversify supplies, encouraging the use of renewables and smartly combine investments and reforms. REPowerEU complements the abovementioned EU Green Deal and fit-for-55 package, designed to help MS in reaching their energy and climate goals. [8]

Referring to the smartness of a building unit, it means the building's ability to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation to the operation of technical building systems, the external environment (including energy grids) and the demands from building occupants. These operations are typically addressed through the performance of building automation and control systems, which are aligned with the building technical systems rather than the building shell [9].

Realising this requirement, the European Commission introduced the **smart readiness indicator** (SRI) under the EPBD that measures a building’s ability to use smart technologies. The SRI rates the smart readiness of buildings (or building units) in their capability to perform 3 key functionalities:

- optimize energy efficiency and overall in-use performance
- adapt their operation to the needs of the occupant
- adapt to signals from the grid (for example energy flexibility).

The SRI will raise awareness of the benefits promised by smart building technologies, such as building automation and electronic monitoring of building systems including heating, hot water, ventilation, lighting, etc. The implementation of the SRI framework supports technological innovation in the construction sector and creates an incentive for the integration of cutting-edge smart technologies in buildings. These technologies aid in decarbonization, while also offering more comfortable and efficient living environments [6].

In addition, the Technical Committee 247 of the European Standardization Organization (CEN) set out to produce many standards relevant to the definition of smart buildings. The 2008 publication of the EN 15232 standard created a mechanism for measuring the intelligence of building automation and control systems. This approach introduced functionality levels, which primarily categorise the degree of intelligence of various building technical systems, as well as services and domains, which serve as the basis for the classification of various building automation and control systems [9].

The EU's goals for energy efficiency have increased dramatically, and the Energy Efficiency Directive (EED), which was updated in 2023, established energy efficiency as a cornerstone of EU energy policy. The updated directive boosts the EU energy efficiency objective and binds Member States (MS) to jointly ensure an additional 11,7% decrease in energy consumption by 2030, compared to the forecasts of the EU reference scenario 2020. Moreover, the yearly energy savings obligation (Article 8) under the amended directive will more than double by 2028, thus meeting the headline target and encouraging energy savings in end-use sectors including industry, transport, and buildings. Member States are therefore required to explore, encourage, and facilitate the application of intelligent and sustainable technology in energy-efficient district heating and cooling systems, energy-efficient infrastructure for heating and cooling, intelligent and efficient buildings, electric vehicles, and industries [10].

Article 8 of the Energy Efficiency Directive (Energy Efficiency Obligation Schemes, EEOS) mandates that Member States (MS) generate energy savings through national energy efficiency policies. There are several challenges associated with this, including avoiding bottlenecks in the participation process, ensuring financing sustainability, identifying and gathering the necessary data from all stakeholders as easily as possible, ensuring the quality and compliance of the energy efficiency (EE) actions, and minimising the risks of fraud. The Measurement, Reporting, and Verification (MRV) framework has also been harmonised with the above-mentioned article, and thus MRV solutions of EEOS and alternative measures have continuously been embraced by national authorities and market stakeholders. Where EEOS have been successfully implemented, the whole energy system benefits (lowered energy costs, avoided costly capacity, deferred network upgrades) [10].

The European Union has implemented several key legislative frameworks to promote smart energy and digitalize its energy systems, aiming to improve efficiency, consumer control, and environmental impact:

- Electricity Directive (EU) 2019/944: Part of the "Clean Energy for All Europeans" package, this directive enhances consumer rights, granting them access to smart meters, real-time consumption data, and energy management tools. It requires Member States to install smart meters for at least 80% of electricity consumers by 2020 where the rollout is cost-effective, improving transparency and enabling demand-side flexibility [11]
- Regulation on the internal market for electricity (EU/2019/943): The objective is to establish a fully integrated, competitive and decarbonized internal electricity market in the EU, ensuring secure and sustainable electricity supply, simultaneously promoting efficiency, innovation and transition to renewable energy [12]
- Governance Regulation (EU) 2018/1999: encourage Member States to integrate digital solutions into their National Energy and Climate Plans (NECPs), fostering the use of advanced data analytics and digital tools for monitoring and optimizing energy consumption [13]
- Energy Efficiency Directive (EU) 2023/1791: The renovated Directive launched in 2023 includes conditions for natural gas and electricity smart metering and encourages the use of smart appliances and demand-response systems to reduce energy consumption during peak demand periods [10]

- Energy Performance of Buildings Directive (EU) 2024/1275: aims to improve the energy efficiency of the buildings by encouraging the integration of smart technologies in buildings which allows better control of energy consumption [6]
- Renewable Energy Directive (EU) 2023/2413: promotes the integration of renewable energy and digital technologies (e.g. smart grids, digital solutions for energy storage) in the energy system [14]
- Cybersecurity Act – Regulation (EU) 2019/881: strengthen cybersecurity in the EU by ensuring that digital solutions in the energy sector are protected from cyber threats and vulnerabilities [15]
- Data Governance Act – Regulation (EU) 2022/868: lays down a framework for data sharing, including energy data and facilitates the use of big data and artificial intelligence in energy systems by ensuring that energy data can be shared securely among stakeholders, enhancing the digital transformation of the energy sector [16]
- Digitalisation of Energy Action Plan: Launched in 2022, this plan includes new regulations to ensure interoperable smart metering and data access. Implementing acts under this plan, such as the one from June 2023, set standards for data sharing between consumers, grid operators, and third parties, enhancing energy services and market integration [17]
- Green Deal and REPowerEU Initiatives: These programs aim to cut greenhouse gas emissions and bolster energy independence. Smart grids and advanced metering infrastructure are central to these goals, supporting renewable energy integration, and giving consumers tools to actively manage their energy use. The initiatives support broader smart grid development, including EV charging and home energy management systems [7,8]

Furthermore, throughout all regions and sectors, barriers of economic, political, regulatory, technological and behavioural nature impede the uptake of energy efficiency solutions and the deployment of renewable energies [18,19,20]. It must be also noted that the market for promoting clean energy products and services is still largely underdeveloped, often due to low levels of consumer awareness, shortage of professional skills, and lack of access to capital [21,22]. But oftentimes regulatory barriers delay the development and scale-up of clean energy business models, despite their potential for economic growth and creation of employment [23].

To address existing barriers, it is essential to develop new business models and markets for sustainable energy services and technologies, improve existing business processes and value chains, and create the right conditions to replicate successful examples, building the capacity of market actors for the clean energy transition. These new or updated business models require collaboration and trust among market actors (even ones who do not have common business cases), which need to be reflected in fit-for-purpose contractual schemes and model agreements.

5 Overview of the smart services and technologies and Business Cases

Within InEExS project, five Business Cases (BCs) were carried out as a basis for identification of fundamental requirements and analysis of the complexities of offering integrated energy services and technologies across domains. The considered business concepts span a wide range of energy services and technologies (space heating/cooling, hot water preparation, e-mobility, renewable energy supply, building renovation), sectors (buildings, transport, tech, energy, and industry -through replication-), carriers (electricity, natural gas) and building infrastructure (smart meters, photovoltaics (PVs), legacy boilers, heat pumps, electric vehicles chargers, new built, historical buildings). The broad range of key engaged stakeholder types, both as project partners (energy supplier in electricity and gas, energy service companies (ESCOs), technology developers, energy management product vendor, energy service developers, Energy cooperative, energy agency, etc.) and already engaged external stakeholders (real estate, buildings managers, maintenance and construction companies, etc.) provide the ground for the successful identification of core barriers, needs, specifications, and solutions.

MRV and Distributed Ledger Technologies (DLT) constitute a core part of the business cases defined within the InEExS project. For each of the five Business Cases (BCs) involved in InEExS, different experts have defined the basis for the MRV and DLT specifications that are needed to develop the pilot projects in the field. Each Business Case uses cutting-edge smart services and/or technologies that are identified and thus prioritised through this document.

5.1 Business Cases in brief

BC1: Recommendations for innovative energy contracts with Pay for Performance guarantee (BEA, OFFIS in DE): The focus of BC1 is on optimising the use of solar energy through households and charging stations for electric cars in a suitable property with an existing business partner, the Charlottenburger Baugenossenschaft eG (short: Charlotte). The utilisation of the solar power produced on the roofs is to be increased to a maximum in the best-case scenario. The solar power can be used in households and at the property's charging points for e-mobility. This means that as little solar power as possible would have to be fed into the grid and residents would use more renewable electricity for the sake of the environment. The aim is to measure the electricity production of the solar plant and visualise it in real time via an app to the tenants towards incentivising the users to directly use the PV-produced energy during the daytime. This is intended to achieve higher capacity utilisation of the PV-system. By installing sensors and using the digital tools, the actual solar power usage can also be determined in the future. This will allow to make recommendations for dynamic electricity tariffs, which are optimised for PV use. Pay4Performance (P4P) contracts will be developed exemplary, based on the increased energy efficiency due to the direct use of PV.

BC2: Improved self-consumption of Distributed Energy Resources (DER) in Energy Cooperatives (ENERCOOP, ESCAN in ES): The primary objective of this BC, titled "Optimised Self-Consumption of Distributed Energy Resources (DER) in Energy Cooperatives for Residential Households" is to enhance the efficiency of collective PV self-consumption within energy community users by implementing incentivisation mechanisms through messages and the utilisation of tokens via Distributed Ledger Technology (DLT) and smart contracts. This BC focuses on identifying and implementing the most effective strategies to maximise the benefits and minimise the costs associated with self-consumption for prosumers within energy communities and the broader energy system. The concept of optimised self-consumption of DER involves enabling and helping prosumers to adapt their energy consumption patterns based on factors such as PV production hours, electricity market price signals, grid conditions, and environmental considerations. Additionally, the BC supports energy efficiency by using an APP that provides tips on both optimised self-consumption of DER and how to reduce the energy demand. As a result, the distribution grid efficiency is also improved due to its better management and congestion reduction.

BC3: Energy efficiency and flexibility services for legacy natural gas boilers (HERON, DOMX in GR): The use case describes how users of legacy natural gas boilers can upgrade their heating systems through a cost-effective IoT controller, while enabling their participation in energy efficiency services to the natural gas supplier. The core innovation of the proposed concept builds on the interconnection of major consuming legacy heating devices (boilers, domestic hot water preparation, radiators, etc.) with the gas network, through the seamless integration of the domx heating controller, towards upgrading existing and long-life cycle building equipment to higher levels of smartness. Targeted devices include residential heating devices operating on natural gas, supporting diverse types of control modes (ON/OFF, power modulation, etc.). The system is interconnected with a cloud-based energy management system that constantly collects, stores and analyses the detailed data collected from connected heating devices. The heating controllers are attached with the boilers of pilot users to enable smart and remote heating control, gas consumption estimation and communication with cloud energy management services over Wi-Fi. The user can interact with the upgraded boiler, both through the existing thermostat and the smartphone application, providing climate comfort limits and collecting real-time feedback on the boiler operation.

BC4: Smart energy management for EV chargers and electricity-based Heating, Ventilation and Air Conditioning (HVAC) appliances (HIVEN in FR; ES & IT): Hiven is a smart home energy management system for connecting and steering smart home appliances over the cloud (Application Programming Interface, API) for the benefit of the consumer, energy company and the grid. EV charging and home heating is shifted to consume energy at the cheapest possible time to save users up to 50% on their cost of energy. Aggregated flexibility is provided to energy companies and grid companies as a service where consumption deviates from the expected profile. In the BC, in addition to researching smart home energy management services further – Hiven will be researching ways to make this consumption profile deviation caused by energy company and grid needs to be transparently reported and compensated. Hiven operates through a B2B2C-model integrating smart charging and smart heating systems as a value add to other existing B2C products such as electric vehicles (EV’s), EV charger applications, Energy company applications etc.

BC5: Decentralised Energy Efficiency Power Plant (IEECP): The Decentralised Energy Efficiency Power Plant (DEEPP) is a theoretical innovative business model that is suggested as an industrial scale solution that integrates sustainable energy technologies and financial innovation to steer energy consumption in commercial and residential buildings and facilitate renovation activity. DEEPP functions as a Virtual Power Plant (VPP) with a unique emphasis on managing demand-side assets, including energy-efficient insulation, batteries, and demand response technologies. It acts as a central platform orchestrating the financing and aggregation of energy efficiency projects, connecting financial institutions, Energy Service Companies (ESCOs), contractors, building owners, and energy utilities. DEEPP relies on Energy Savings Agreements (ESAs) as the financial foundation for project funding. ESAs serve as the demand-side equivalent of Power Purchase Agreements (PPAs) used in traditional power plant financing, provided by financial institutions, such as banks. DEEPP's core operation involves partnering with ESCOs and contractors to execute comprehensive building retrofit projects aimed at enhancing energy efficiency and power system interaction by installing advanced insulation and demand-side equipment to achieve energy savings and respond to signals according to the needs of the grid. Financial flows to DEEPP from building owners are linked to the actual energy savings realised, as confirmed by the issuance of Energy Service Contracts (ESCs) by a third party that is trusted to quantify and certify energy savings. Repayments ensure a transparent and reliable financial structure.

5.2 Smart services and technologies

This chapter identifies and describes some of the most relevant and innovative smart services and technologies that can be integrated into the various sectors. Table 1 shows smart services and technologies that were used, implemented or developed within InEExS Business Cases, according to their description in the previous subchapter.

Table 1 Products and Services used and implemented within Business Cases

BC1 (BEA)	BC2 (ENERCOOP)	BC3 (HERON)
Products & Services		
a) providing modern meters to record PV production, PV consumption and energy consumption in total b) Software to monitor PV production, consumption and energy consumption and to inform tenants about it to incentivise the use of solar PV at the time of production for EV-charging and in the households (via an App)	a) collective PV self-consumption without upfront investment b) providing a user application that will incentivise the use of solar PV at the time of production (ToU tariff) c) other services such as PV charging or energy efficiency	a) DOMX's Smart Controller b) DOMX's smartphone application c) DOMX's Measurement & Verification (M&V) approach for energy savings calculation based on Machine Learning (ML) d) DLT technology to verify P4P schemes
BC4 (HIVEN)	**BC5 (IEECP)**	
Products & Services		
a) steering home appliances over API **b) smart EV chargers**	a) no upfront cost provision of energy retrofits to buildings, including heat pumps and on-site RES. These automatically participate in the energy market as negative baseload	

c) smart home energy management **d) application for smart charging preferences & data frequency**	energy/megawatts, as RES production/self-consumption, and as flexibility (RES, Heat Pumps). b) comprehensive support for energy efficiency retrofits across the value change. c) marketplace platform for aggregation of services and financing. d) financial flow governance through Service Level Agreements (SLAs) and Energy Savings Agreements (ESAs) verified and controlled using smart metering for M&V. e) open, trusted calculations of energy savings and flexibility services happening on the cloud or DLT.

Overview of viable Smart services and technologies

Below is an overview of the relevant smart services and technologies that are currently available on the market. Additionally, it shows which sectors can use listed smart services and technologies, which type of energy they can influence on and which BC employs which smart service or technology.

1. Smart Metering and Energy Management Systems

- Description: Firstly, smart meters are devices which allow to frequently measure energy production or consumption which are a critical component of a smart energy distribution grid. They are enabled with uni/-bidirectional communication that allows collection of data on the electricity produced and fed to the power grid or the one consumed by customers, to execute control commands to then provide such data to the company for better monitoring and billing. From SM systems, three major benefits are: the availability of energy consumption information to users, which enables them to optimise their consumption, the ability to assess and control meters remotely, and the ability to reduce energy waste, since it can be automated to react to power shortages, failures, and excesses. Secondly, Energy Management Systems (EMS) can be applied in single dwellings (Home Energy Management System, HEMS) to control house appliances (e.g. washing machines, dishwashers) but also thermostats, air-conditioners, or electric water heaters (i.e. thermostatically controlled appliances). Also, EMS can be scaled up to manage a set of dwellings (Building Energy Management System, BEMS) that are using RE production facilities or central heating stations, to keep similar comfort levels in all dwellings, simultaneously dealing with building energy savings due to better performance. District Energy Management System (DEMS) is the highest level of EMS, which includes sets of buildings and interactions between them (e.g. district heating systems or solar/wind farms) [24].
- Sectors Involved: Residential, Commercial, Industrial
- Energy Carriers: Electricity, Gas, Water
- Business Cases: BC1, BC2, BC3, BC4, BC5

2. Demand Response Programs (DRP)

- Description: Demand response is the term used to describe flexible power demand that can be changed at certain periods, such as to take advantage of high wind generation or reduce demand peaks. This may help to integrate variable renewable generation and new electric loads cost-effectively [25]. The main aim of DRPs is to encourage people to reduce their consumption during peak hours through incentives offered by utility companies. However, DRPs cannot control electricity consumption on their own without the participation of consumers. DRPs are generally divided into incentive-based programs such as direct load control, demand bidding programs, and interruptible tariffs or price-based programs such as real-time pricing (RTP), critical peak pricing (CPP), day-ahead, etc. [26].

- Sectors Involved: Residential, Commercial, Industrial
- Energy Carriers: Electricity
- Business Cases: BC2, BC3, BC4, BC5

3. Integrated Renewable Energy Systems (IRES)

- Description: with IRES, nearby renewable energy sources' energy potential is used to meet a remote place's energy needs. This technology allows for the generation of power from a variety of renewable energy sources. Integrated use of different renewable energy resources minimizes energy storage requirements and increases the reliability of power supply and quality of power. For stand-alone applications, these systems are always incorporated with storage devices to manage the stochastic behaviour [26,27].
- Sectors Involved: Residential, Commercial, Industrial
- Energy Carriers: Electricity
- Business Cases: BC1, BC2

4. Building Automation Systems (BAS)

- Description: BAS is a data acquisition and control system that incorporates various functionalities provided by the control system of a building. BAS is also known as Energy Management Control Systems (EMCS), Building Management Systems (BMS), Building Energy Management Systems (BEMS), Facility Management Systems (FMS), and Building Automation and Control System (BACS). Common functionalities of BAS are temperature and air quality monitoring, lighting system control, Heating, ventilation, and air conditioning (HVAC) system control, electricity control, access control, security control, fire control, and sending signals when faults occur [28].
- Sectors involved: Residential, Service, Industry
- Energy carriers: Electricity, Gas, Water
- Business Cases: BC4

5. Virtual Power Plants

- Description: Virtual power plants represent the most immediate future of electricity generation, as they allow for intelligent consumption of energy in a distributed environment through the optimal management of demand and power generation. Users generate and utilize their own energy as a result, which encourages greater active consumer involvement in decision-making. Consumers trade their surplus electrical energy in the market at the desired price without a third party's interference. On the one hand, prosumers who install any small-scale RESs or storages (i.e., batteries, EVs) can trade in the market since the scheduling algorithm maximizes their surplus energy. On the other hand, customers without any RES and storage can participate by load shifting, peak clipping, valley filling, etc. [29] Additionally, VPPs are helpful instruments for integrating renewable energy and enhancing grid balance. They more effectively offset any

variations in output and demand from projections. Another important advantage of VPPs is the integration of electric vehicle load management, as this combines the storage systems and controllable loads offered by the vehicle-to-grid (V2G) service [30].
- Sectors involved: Residential, Service, Industry
- Energy carriers: Electricity
- Business Cases: BC5

6. Vehicle-to-Grid (V2G) Technology

- Description: The V2G system offers an incentive-pricing structure that encourages electric vehicle (EV) owners to participate in this charging/discharging system. In this concept, EVs are integrated as an additional element of the grid infrastructure. With this concept, owners of electric vehicles can charge their vehicles more affordably when there is excess and unused power in the grid during off-peak demand. On the other hand, they can more expensively release the excess power that is stored in their batteries into the grid during periods of on-peak demand when there is a shortfall in the grid system. However, the V2G as a new system has several limitations like battery wearing, limited charging stations and related equipment, high needed investment, and so on [31].
- Sector involved: Transport
- Energy carriers: Electricity
- Business Cases: BC4

7. Blockchain for Energy Trading (P2P transactions)

- Description: In P2P trading, prosumers can actively trade energy with one another in real-time and facilitate a sustainable and reliable generation and consumption of energy within the community [32]. P2P allows prosumers to trade excess energy production with their peers and increase their benefits and consumer benefit. Also, P2P energy trading offers end users greater flexibility, increasing their chances to use clean energy and contributing to the shift to a low-carbon energy system. Additionally, the other actors in the electricity market can obtain benefits, such as reducing the peak demand for electricity, reducing maintenance and operation costs, and improving the reliability of the electrical system [33].
- Sector involved: Residential, Business, Industry
- Energy carriers: Electricity
- Business Cases: BC2

8. Energy-as-a-Service (EaaS):

- Description: Energy as a service (EaaS) is an emerging business model that enables otherwise passive energy consumers to play an active role and participate in energy utility services [34]. EaaS is a service-oriented energy business model that involves providing electricity supply, energy management, and energy efficiency services focused on local generation and consumption [35]. In this disruptive model, the customer pays a flat monthly fee covering all their energy needs, ranging from heating and cooling to EV charging, and will earn full benefits from the renewable-generated energy or battery technologies they own – all delivered through a single provider and a single contract. Meanwhile, the provider will manage the full portfolio of technologies on the customers' site and any connected sites, to the full advantage of the customer. This includes reducing peak time consumption using local storage systems, bidding the customer's load into the flexibility frequency reserve markets, managing their consumption to maximize the use of their PV, allowing them to benefit from a local peer-to-peer trading system, optimizing their electric vehicle charging, etc. [36].

- Sectors involved: Residential, Service, Industry
- Energy carriers: Electricity
- Business Cases: BC2, BC4

9. Smart Grids (SG)

- Description: an Intelligent Electric Power Distribution Network or Smart Grid is a network that intelligently integrates new technologies to improve the monitoring and control of the operation of electrical systems [37]. A smart grid is an electricity network that delivers electricity in a controlled way (from the generation points to the consumers). The main goal is to use information and communication technologies to create reliable, efficient, and interactive networks [38]. The smart grid shifts the current conventional grid into a more modernized grid that can function cooperatively and responsively. Users, generators, and consumers may intelligently be integrated into the grid to provide efficient, secure, and economically feasible supplies. The SG incorporates distributed intelligence, bi-directional-based infrastructure for communications, and power flow to improve system efficiency, reliability, and sustainability. Furthermore, the smart grid is a network that integrates digital computing capabilities and highly automated services into the already existing power system infrastructure. Empowering the transition toward the smart grid enhances the robustness and self-healing capabilities of the system [39].
- Sectors involved: Industry, Service, Residential
- Energy carriers: electricity
- Business Cases: BC2, BC4

6 Roadmap on overcoming barriers in regulation, finance and market design at the Member State and EU level for smart services and technologies

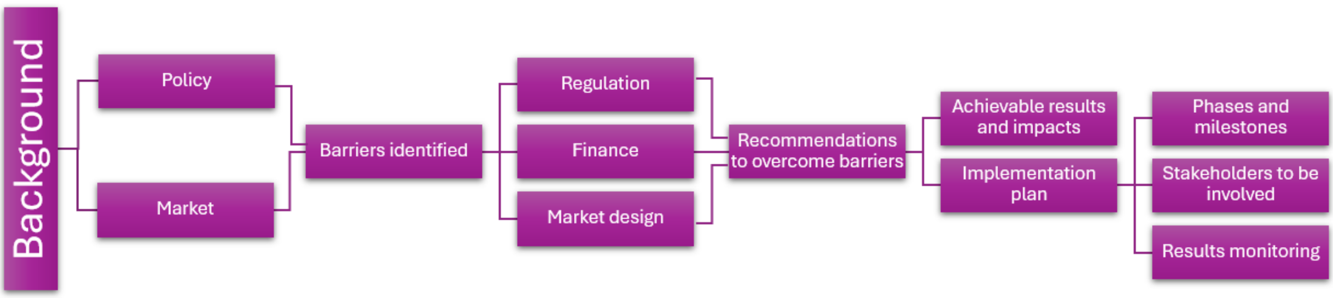
6.1 InEExS approach

This Roadmap's methodology is the combination of literature analysis, known practices in the Business Cases and survey results from InEExS project. Firstly, legislative documents on the EU level, such as Energy Efficiency Directive (2023/1791 EU) [11], Electricity Directive (2019/944 EU) [12], Energy Performance of Buildings Directive (2024/1275 EU) [6] were identified and served as a basis for deeper understanding of the existing framework and identification of inconsistencies and gaps, which eventually lead to identification of barriers. Moreover, literature review, i.e. examining existing research, reports and case studies, using keywords such as "barriers, smart services, technologies, buildings, regulatory, financial market, policy, recommendation", was conducted, to map existing knowledge and identify barriers in practice, using the most recent references, from 2020 onwards.

As DLT is a core technology for the InEExS project, it is necessary to analyse the market and examine the use of blockchain technology (one type of DLT) in the energy sector, as well as other smart energy services. More specifically, the first step of the overall process is the overview of the current state, serving as a cornerstone for examining literature, engaging stakeholders and gathering data about policies and market, specific to each country or region. Thus, 18 barriers were identified, both through literature analysis and implementation of business cases/models within the project. As this document's objective is to overcome barriers mentioned above, the recommendations were given to cover all main intervention, regulatory, finance and market areas.

Finally, as the ultimate step of the document, recommendations for future implementation of the smart services and technologies were given through the implementation plan which contains phases, key milestones, relevant stakeholders and monitoring indicators. Methodological approach, used to identify barriers and propose recommendations is given in Figure 1.

Figure 1 Methodological approach



6.2 Legal, financial and market design background

Within each Business Case (BC), facilitators assessed the project's legal implications of the project. According to the literature review and the information about Business Cases within the InEExS project, an analysis was conducted to present an overview of the legal, financial and market design background and the barriers that hinder the implementation.

6.2.1 Identification and analysis of the barriers

In this section, we conducted a barrier analysis for smart service and technology implementation and address the following questions:

1. What are the different barriers impeding the successful integration of smart services and technologies in business cases?
2. What are the barriers impending the successful integration of blockchain technologies in business cases?
3. Which actors are affected the most by the barriers and how?
4. Why is this barrier relevant to successful integration of smart services and blockchain technologies?
5. How can policy address these barriers to accelerate and facilitate the integration of smart services and blockchain technologies?

We employ an approach integrating qualitative methods such as literature reviews and the results of interviews and workshops that project partners had with their stakeholder within InEExS project. There were two rounds of workshops: 19 meetings/workshops with 82 participants in the first round, and 13 meetings/workshops with 35 participants in the second. As a result, a respectable number of stakeholders participated, offering insightful comments and fruitful discussions. Conceptualisation of the results is given below, through regulatory (Table 2), finance (Table 3) and market (Table 4) barriers.

Table 2 Regulatory barriers

Barrier	Explanation	Who is affected the most	Why is important?	Identified in BC
Regulatory barriers to grid integration of renewable energy and distributed energy resources (DER) [15,40,41,42]	Lack of regulatory framework related to integrating renewable energy and distributed energy sources into the grid. This includes grid feed-in limitations, inefficiencies in integration of distributed energy sources and lack of supporting regulations for P2P energy trading	**Renewable energy producers/prosumers** can face restrictions or financial disincentives for feeding surplus energy into the grid, thus reducing returns on investments. **Grid operators** struggle with managing decentralized and intermittent energy resources, causing inefficiencies. **Energy cooperatives** cannot implement decentralized models like P2P trading due to unclear regulations. **Consumers** can miss opportunities for cost savings through local renewable energy usage.	Effective integration of renewables and distributed energy sources is critical for decarbonizing the energy system, maximizing local energy use, and reducing grid strain	BC1, BC2, BC4, BC5
Data privacy and energy data regulations [43]	Regulations such as GDPR, i.e. General Data Protection Regulation protects individuals' personal data and ensure their privacy rights are respected. It also restrict the collection, processing and sharing of consumer energy data, hindering the adoption of	**Technology providers** face challenges in designing systems that comply with GDPR **Consumers** may not want to share their data, thus reducing the effectiveness of personalized energy optimization services **Energy companies and grid operators** struggle to collect and analyse energy data needed for efficient operations	Strict data privacy regulations may limit real-time monitoring of energy consumption, impacting energy optimisation and also impede the progress of technologies	BC1, BC2, BC3, BC4, BC5

	real-time monitoring and optimisation tools	App developers struggle to design new or update existing apps due to lack of available energy data		
Lack of regulatory support for energy communities [44,45]	Lack of recognition and regulatory support for energy communities across Member States, despite EU directives to empower them. Including lack of complete and clear definition of both renewable energy community (REC) and citizen energy community (CEC).	**Energy communities** face legal uncertainty and administrative barriers, limiting their ability to operate. **Consumers/prosumers** miss opportunities for participation in community-driven renewable energy initiatives. **Policymakers** struggle to create harmonized frameworks for energy community growth.	Energy communities are essential for localizing renewable energy adoption and democratizing the energy market, directly contributing to EU renewable energy targets.	BC2, BC5
Building regulations and energy-efficient retrofitting [6,45]	Outdated or fragmented building regulations do not encourage or support energy-efficient retrofitting and integration of smart services and technologies	**Building owners** lack financial and regulatory motivation to invest in retrofitting. **Contractors and ESCOs** experience reduced demand for retrofitting projects. **Energy companies** cannot leverage energy savings achieved through retrofitting.	Retrofitting is vital for reducing energy consumption and emissions in the building sector, a significant contributor to EU climate goals. Regulatory updates would accelerate renovations and energy efficiency.	BC3, BC5
Regulatory gaps in demand response participation and consumer flexibility compensation [11,46]	Regulatory gaps that prevent full consumer participation in demand response programs and lack mechanisms to transparently compensate consumers for shifting	**Consumers** lack financial motivation to participate in demand response, missing opportunities for cost savings. **Grid operators** lose a key tool for balancing supply and demand effectively. **Energy companies** face challenges engaging consumers in flexibility services.	Demand response is crucial for integrating renewables, stabilizing grids, and optimizing energy costs, but remains underutilized without proper incentives and frameworks.	BC4, BC5

	energy usage based on grid needs.			
Virtual power plant (VPP) regulations [11,47]	Lack of regulatory clarity for operating Virtual Power Plants (VPPs), which aggregate and manage demand-side assets like batteries and demand response technologies.	**VPP operators** face legal uncertainties that hinder scaling operations. **Grid operators** miss opportunities to balance the grid using aggregated flexibility. **Building owners** cannot fully benefit from VPPs' energy and cost savings potential.	VPPs are vital for managing decentralized energy systems and balancing grid loads, particularly as renewable energy sources grow. Clear regulations would accelerate their deployment.	BC5
Transition policies for natural gas systems [48,49]	Policies emphasizing the phase-out of natural gas may deprioritize innovations aimed at improving the efficiency of existing gas-based systems.	**Gas network operators** receive reduced investment in infrastructure upgrades. **Consumers** continue using inefficient systems without retrofit incentives. **Innovators** face reduced demand for innovations in gas technologies	Supporting interim improvements in natural gas systems can enhance energy efficiency during the transition to renewable energy, reducing emissions from existing infrastructure.	BC3

Table 3 Financial barriers

Barrier	Explanation	Who is affected the most	Why is important?	Identified in BC
Limited access to financing for renewable energy and DER projects [50,51]	Difficulty in securing adequate and affordable financing for renewable energy installations and DER projects, particularly small-scale projects or community-led initiatives. This includes lack of information in financing institutions on what are energy communities.	**Energy communities and prosumers** struggle to fund initial investments for DER installations like PV panels or batteries. **Small energy cooperatives** have limited access to capital slows the development of community energy projects. **Technology providers** have reduced market opportunities due to constrained demand.	Financing is a critical enabler for renewable energy adoption and DER deployment, which are central to achieving EU decarbonization goals. Without accessible financing, small and medium players are excluded, limiting overall system transformation.	BC1, BC2, BC5
High upfront costs of energy efficiency and retrofitting projects [6,52]	The significant initial investment required for energy-efficient retrofits, DER installations, and infrastructure upgrades acts as a deterrent for stakeholders.	**Building owners** often lack capital for retrofitting projects, even if they yield long-term savings. **Energy companies** struggle with reduced uptake of energy efficiency projects that affects their ability to achieve energy-saving targets. **Consumers** struggle with high costs that eventually prevent the adoption of energy-efficient technologies like IoT controllers and advanced boilers.	High upfront costs hinder widespread adoption of energy-efficient technologies, slowing progress toward emissions reduction and energy-saving objectives.	BC3, BC4, BC5
Lack of standardized financial models and incentives [51,53]	Absence of consistent and transparent financial mechanisms, such as standardized contracts, subsidies, and tax incentives,	**Energy cooperatives** are facing an inconsistent incentives that reduce community-driven energy projects' feasibility.	Standardized financial models reduce risks, simplify participation, and attract broader stakeholder involvement in the energy transition.	BC1, BC2, BC5

	limits participation in energy projects.	Investors struggle with unclear financial models which make investments riskier, leading to lower capital availability. Consumers are discouraged by lack of incentives like tax breaks or feed-in tariffs		
Insufficient monetization mechanisms for demand flexibility [11]	Limited or unclear mechanisms for monetizing demand-side flexibility, such as demand response or aggregated services, reduce the economic viability of these solutions.	**Consumers and prosumers** are discouraged by lack of financial compensation **Grid operators and energy companies** miss opportunities to reduce peak loads and balance the grid effectively. **VPP operators** struggle with reduced profitability that hinders scaling up aggregated services.	Demand-side flexibility is essential for integrating renewables, balancing the grid, and reducing costs. Without proper compensation mechanisms, its potential remains underutilized.	BC4, BC5
Regulatory complexity in accessing public or EU funds [54]	Complex administrative procedures and regulatory hurdles make it difficult for stakeholders to access EU funding programs or public grants for energy projects.	**Small and medium enterprises** (SMEs) often do not have resources to navigate complex application processes for public funding. **Energy communities** are facing administrative burdens that discourage them in participating in EU funding schemes. **Project developers** struggle with delayed or failed applications that can slow down project timelines.	Simplified access to public and EU funds ensures that diverse stakeholders, including small players, contribute to the energy transition.	BC1, BC2, BC5
Risk aversion among financial institutions [55,56]	Financial institutions' hesitancy to fund innovative or unproven energy technologies due to	**Innovators and technology providers** struggle to secure funding for cutting-edge solutions like blockchain-based P2P trading.	Addressing risk aversion unlocks investments in transformative technologies critical for the energy transition.	BC1, BC2, BC5

	perceived risks limits capital availability.	**Energy cooperatives** can lack financial support for community energy projects **Building owners** are unable to access loans for retrofitting projects due to financial institutions' risk concerns.		

Table 4 Market barriers

Barrier	Explanation	Who is affected the most	Why is important?	Identified in BC
Lack of similar case studies in the EU using blockchain	This barrier refers to the limited availability of proven use cases or examples within the EU that demonstrate the practical application and benefits of blockchain in energy markets, such as peer-to-peer (P2P) energy trading, demand response, or decentralized energy management.	**Energy companies and developers** struggle to justify the business case for blockchain-based energy solutions due to lack of proven case studies **Consumers and energy communities** may hesitate to participate in blockchain-based energy models due to unfamiliarity and perceived risks **Policymakers and regulators** face difficulty in crafting supportive regulatory frameworks due to a lack of real-world evidence on blockchain's impact and feasibility	It limits the ability to scale and integrate blockchain technologies into EU energy markets. Addressing it would require targeted efforts, such as pilot projects, shared learning platforms, and industry collaboration to build a robust portfolio of case studies.	BC1, BC2, BC3, BC4, BC5
Possibility of using aggregated offers and bids [11,12,57]	Insufficient mechanisms for aggregating decentralized energy resources (DERs) such as EV chargers, HVAC appliances, batteries, and demand response capacities into single offers or bids for energy markets. This limits effective	**Energy companies** can have a limited ability to create aggregated offers, but also can miss opportunities for monetizing aggregated flexibility services **VPP Operators and Energy communities** face difficulty in	Aggregated offers and bids are critical for integrating small-scale energy resources into larger energy markets, enabling decentralized energy systems to participate effectively.	BC4, BC5

	participation in demand-side flexibility and grid-balancing services.	monetizing aggregated resources due to fragmented market rules. **Grid operators** suffer from missed opportunities to utilize aggregated resources for balancing and reliability. **Consumers and prosumers** miss financial benefits from aggregated bids and offers		
Insufficient market access for smart services and technologies [11,58]	This barrier refers to the limited opportunities and frameworks for integrating smart energy services and technologies—such as demand response, distributed energy resources (DERs), and energy management systems—into traditional energy markets.	**Prosumers and consumers** face challenges in selling energy surplus or participating in DRPs, leading to underutilization of their assets. **Technology providers** face limits in their business opportunities. **Grid operators** face impediments in grid optimisation and efficient incorporation of RES.	It limits the adoption of smart technologies, hinders renewable energy integration, and restricts consumer participation, slowing the transition to efficient and decentralized energy systems.	BC4, BC5
Fragmented market rules for energy trading [11,58]	Different market rules across Member States hinder cross-border P2P trading and community energy participation.	**Consumers and prosumers** face confusion and operational difficulties and sometimes lack of possibility of P2P. **Investors** face increased risk due to inconsistency in frameworks	Fragmented regulations create market inefficiencies and discourage cross-border energy projects, limiting renewable energy expansion	BC1, BC2, BC5
Limited consumer awareness and participation [11,59,60]	This barrier refers to the lack of consumer knowledge, understanding, or engagement regarding energy market opportunities, such as dynamic pricing, demand-side flexibility programs, peer-to-peer (P2P)	**Consumers** often miss opportunities to reduce costs or generate income. **Energy communities and cooperatives** face difficulty in mobilizing participation due to a lack of consumer understanding of community	This barrier limits consumer engagement, slows the adoption of renewable energy and smart technologies, reduces cost-saving opportunities, and weakens the effectiveness of decentralized energy systems and grid stability.	BC1, BC2, BC4

	trading, and renewable energy community benefits.	energy benefits and difference with collective self-consumption. **Energy companies and aggregators** experience the reductions in effectiveness of demand-side management projects due to limited consumer engagement		

6.3 Regulatory, finance and market recommendations for overcoming barriers

The identified barriers proved that careful planning is necessary for integration of innovative technologies into business cases to be both helpful, financially viable but also attractive and easy to use. Since there are many obstacles that must be overcome, a set of recommendations for each recognized barrier are given below.

6.3.1 Regulatory recommendations

6.3.1.1 Standardisation of grid integration frameworks for renewables and distributed energy sources

Barrier addressed:

- Regulatory barriers to Grid Integration of Renewable Energy and distributed energy sources.

Definition of the recommendation:

- create a national framework for integrating renewables and DERs into the grid, ensuring uniform rules for feed-in tariffs and clear guidelines for P2P energy trading.

Actions that need to be taken:

- develop a national regulatory framework aligning with EU directives
- simplify grid connection processes for small-scale DERs
- standardize dynamic pricing models and feed-in tariffs.

Level of application:

- Member State level for policy creation and implementation.

How to implement recommendation:

- form working groups with grid operators, policymakers, and renewable energy stakeholders
- pilot DER integration and P2P trading in specific regions to test and refine frameworks
- publish national guidelines for DER integration.

Involved actors:

- Member State governments, grid operators, energy companies, technology providers, renewable energy providers.

Why is this recommendation important:

- reduces regulatory fragmentation, encouraging DER and renewable energy adoption and enhances grid stability.

Expected benefits:

- increased renewable energy utilization
- reduced dependence on fossil fuels
- empowered prosumers through transparent compensation mechanisms.

6.3.1.2 Development of GDPR-Compliant Energy Data Platforms

Barrier addressed:

- Data privacy and Energy Data Regulations.

Definition of the recommendation:

- create secure, interoperable platforms for energy data sharing that comply with GDPR while enabling real-time optimization.

Actions that need to be taken:

- define national guidelines for energy data sharing under GDPR
- develop interoperable systems for secure data exchange between stakeholders
- incentivize utilities and companies to adopt interoperable platforms
- fund research into secure energy data solutions.

Level of application:

- Member States for national GDPR-compliant guidelines; industry level and SMEs for platform development.

How to implement recommendation:

- fund research and development of interoperable data platforms
- partner with technology providers and energy companies to develop platforms
- ensure stakeholder collaboration to design user-friendly and secure systems
- training for data protection officers in the energy sector
- monitor compliance through audits and certifications.

Involved actors:

- Data Protection Authorities, energy companies, technology developers, consumer advocacy groups.

Why is this recommendation important:

- enables optimization of energy systems while protecting consumer privacy.

Expected benefits:

- improved energy efficiency
- empowered consumers through data-driven insights and transparent data use
- accelerated adoption of smart energy systems.

6.3.1.3 Providing consistent support for energy communities

Barrier addressed:

- Lack of regulatory support for Energy Communities.

Definition of the recommendation:

- ensure legal recognition and provide administrative and financial support for energy communities.

Actions that need to be taken:

- align national laws with EU definitions for energy communities
- simplify administrative processes for establishing and operating energy communities
- provide grants or subsidies for community-driven renewable projects.

Level of application:

- national level for standardization; local level for implementation.

How to implement recommendation:

- amend national laws to align with EU definitions
- launch a national energy community support program
- provide local governments with grants and subsidies to support energy communities
- monitor project outcomes to ensure effectiveness.

Involved actors:

- Member States, local governments, community organizations, NGOs.

Why is this recommendation important:

- promotes local renewable energy projects, fosters local engagement and enhances energy independence.

Expected benefits:

- increased renewable energy capacity
- strengthened community engagement in the energy transition
- enhanced local economic development.

6.3.1.4 Update of building regulations to mandate energy efficiency retrofits

Barrier addressed:

- Building regulations and energy-efficient retrofitting.

Definition of the recommendation:

- revise national building codes to mandate retrofits for energy efficiency and provide financial incentives for compliance.

Actions that need to be taken:

- align national building codes with EU efficiency targets
- mandate retrofits for public and private buildings by set deadlines
- offer tax credits, low-interest loans, and grants for retrofits
- introduce penalties for non-compliance with energy efficiency standards.

Level of application:

- Member State level for harmonization and implementation.

How to implement recommendation:

- launch national programs for retrofitting public and private buildings
- launch national awareness campaigns about retrofit benefits
- engage ESCOs and contractors to ensure smooth implementation
- monitor progress through energy audits.

Involved actors:

- national governments, ESCOs, building owners, contractors, financial institutions.

Why is this recommendation important:

- reduces emissions and energy consumption in the building sector, a major contributor to climate change.

Expected benefits:

- lower energy costs for building occupants
- reduced carbon footprint in the building sector
- job creation in construction and retrofitting industries.

6.3.1.5 Enabling Demand Response and Consumer Compensation Mechanisms

Barrier addressed:

- Demand Response Participation and Consumer Flexibility Compensation.

Definition of the recommendation:

- establish clear national frameworks and compensation mechanisms for consumer participation in demand response programs.

Actions that need to be taken:

- create national regulations for demand response participation
- define transparent compensation models for flexibility services
- pilot demand response programs to refine mechanisms.

Level of application:

- Member State level for policy frameworks and rollout.

How to implement recommendation:

- work with utilities and aggregators to design programs
- engage consumers through awareness campaigns
- monitor program success and consumer satisfaction

Involved actors:

- Member State governments, energy companies, consumer groups, grid operators.

Why is this recommendation important:

- encourages consumer participation in stabilizing grids and integrating renewables.

Expected benefits:

- enhanced grid flexibility and stability
- lower energy costs for consumers
- increased renewable energy integration.

6.3.1.6 Clarification of regulations for Virtual Power Plants

Barrier addressed:

- Virtual Power Plant (VPP) Regulations.

Definition of the recommendation:

- establish clear regulatory frameworks for VPPs to aggregate and manage distributed energy resources.

Actions that need to be taken:

- establish clear definitions and operational standards for VPPs
- provide incentives for VPP development and participation
- support pilot VPP projects to test and refine regulations

Level of application:

- Member State level for policy guidelines and execution

How to implement recommendation:

- work with VPP operators and grid stakeholders to draft operational standards
- launch pilot VPP projects to test and demonstrate value
- publish national VPP guidelines based on pilot outcomes.

Involved actors:

- Member State governments, grid operators, VPP developers, energy companies.

Why is this recommendation important:

- enables the aggregation of decentralized energy resources to improve grid efficiency and resilience.

Expected benefits:

- improved grid efficiency and resilience
- greater adoption of renewable energy
- cost savings through demand-side management.

6.3.1.7 Balancing natural gas transition policies

Barrier addressed:

- Transition Policies for Natural Gas Systems.

Definition of the recommendation:

- incorporate interim support for improving natural gas systems during the transition to renewable energy.

Actions that need to be taken:

- offer grants or tax incentives for retrofitting gas infrastructure
- encourage the development of hybrid systems combining gas and renewables
- phase out inefficient systems with a clear timeline
- ensure policies support innovations in gas technologies.

Level of application:

- Member State level for transitional strategies, local level for implementation.

How to implement recommendation:

- collaborate with gas operators to identify retrofit opportunities
- use public-private partnerships to fund hybrid systems
- monitor emissions reductions from retrofits.

Involved actors:

- national governments, gas network operators, energy companies, financial institutions.

Why is this recommendation important:

- maintains energy system reliability while reducing emissions from existing gas infrastructure.

Expected benefits:

- improved efficiency of gas systems
- reduced emissions during the energy transition
- continued energy access for consumers reliant on gas.

6.3.2 Financial recommendations

6.3.2.1 Creation of National Green Energy Funds

Barrier Addressed:

- Limited Access to Financing for Renewable Energy and DER Projects.

Definition of the recommendation:

- establish state-managed funds to pool public and private capital for financing renewable energy and DER projects.

Actions that needed to be taken:

- launch state-level green energy funds
- provide low-interest loans and grants for renewable projects
- develop partnerships with local banks and financial institutions.

Level of application:

- Member State level for fund creation and distribution.

How to implement recommendation:

- legislate to establish green funds
- coordinate with private banks for co-financing
- develop online portals for simplified applications.

Involved actors:

- national governments, regional authorities, local banks, SMEs, renewable energy stakeholders.

Why is this recommendation important:

- improves financial accessibility for renewable projects at the local level, supporting national energy goals.

Expected benefits:

- accelerated renewable energy deployment
- increased regional economic activity
- enhanced energy security.

6.3.2.2 Development of targeted subsidies and loan programs for retrofitting

Barrier addressed:

- High Upfront Costs of Energy Efficiency and Retrofitting Projects.

Definition of the recommendation:

- subsidies, tax breaks, and low-interest loans to make retrofitting more accessible.

Actions that needed to be taken:

- establish retrofitting funds at the national level
- partner with Energy Service Companies (ESCOs) to deliver projects
- provide financial incentives for early adopters of energy-efficient technologies.

Level of application:

- Member State level for program execution; EU level for policy alignment.

How to implement recommendation:

- launch awareness campaigns about retrofitting benefits
- simplify access to subsidies through digital platforms
- collaborate with banks to offer affordable loans for retrofitting.

Involved actors:

- national governments, ESCOs, financial institutions, building owners.

Why is this recommendation important:

- reduces cost barriers, ensuring greater uptake of energy efficiency solutions.

Expected benefits:

- reduced energy consumption and costs
- lower carbon emissions from the building sector
- job creation in retrofitting industries.

6.3.2.3 Standardization of renewable energy incentives

Barrier Addressed:

- Lack of Standardized Financial Models and Incentives.

Definition of the recommendation:

- harmonize feed-in tariffs, renewable energy purchase agreements (REPAs), and other incentives at the national level.

Actions that needed to be taken:

- introduce standard feed-in tariffs and incentives for renewable energy projects
- develop uniform contract templates for REPAs
- establish risk-sharing mechanisms for investors.

Level of application:

- Member State level for legislative and regulatory action.

How to implement recommendation:

- create working groups with policymakers, energy companies, and regulators
- roll out pilot programs to test standardized financial instruments
- publish templates and guidelines for stakeholders.

Involved actors:

- national governments, energy regulators, energy companies, financial institutions.

Why is this recommendation important:

- streamlines renewable energy investments and reduces investor uncertainty.

Expected benefits:

- consistent investment environment
- faster renewable energy project approvals
- increased capacity for renewable energy production.

6.3.2.4 Monetization of demand flexibility with dynamic pricing

Barrier Addressed:

- Insufficient Monetization Mechanisms for Demand Flexibility.

Definition of the recommendation:

- introduce dynamic pricing and consumer compensation schemes to incentivize demand-side flexibility.

Actions that needed to be taken:

- implement real-time pricing models in electricity markets
- develop compensation mechanisms for demand response participation
- aggregate consumer demand response for market trading.

Level of application:

- EU electricity markets; Member State level for rollout.

How to implement recommendation:

- pilot dynamic pricing programs with grid operators
- partner with energy companies to create compensation schemes
- educate consumers on financial benefits of participating in demand response programs.

Involved actors:

- EU policymakers, grid operators, energy companies, consumer advocacy groups.

Why is this recommendation important:

- unlocks the potential of demand-side flexibility, enhancing grid stability and renewable integration.

Expected benefits:

- improved grid reliability
- lower peak energy demand
- financial savings for consumers.

6.3.2.5 Simplification of the access to state and public funds

Barrier addressed:

- Regulatory Complexity in Accessing Public or EU Funds.

Definition of the recommendation:

- streamline applications for national and EU funding to reduce administrative burdens.

Actions that needed to be taken:

- develop centralized state-level digital platforms for funding applications
- provide multilingual guidance and technical support for applicants
- simplify documentation requirements for small-scale projects.

Level of application:

- Member State level for platform creation and fund distribution.

How to implement recommendation:

- create online portals for funding applications
- offer training workshops for small and medium-sized enterprises (SMEs)
- appoint local coordinators to assist with applications.

Involved actors:

- national governments, regional authorities, SMEs, community energy organizations.

Why is this recommendation important:

- encourages broader participation in funding programs and reduces barriers for small players.

Expected benefits:

- faster project approvals and implementation
- broader participation in the energy transition
- reduced administrative overhead for applicants.

6.3.2.6 Launch of risk-sharing mechanisms for high-risk projects

Barrier addressed:

- Risk Aversion Among Financial Institutions

Definition of the recommendation:

- EU-backed guarantees and insurance for innovative or high-risk renewable energy projects.

Actions that needed to be taken:

- create a risk-sharing fund for renewable projects
- offer partial guarantees for emerging technologies
- encourage public-private partnerships to share risks.

Level of application:

- EU level for fund creation; Member State level for project deployment.

How to implement recommendation:

- partner with banks and insurers to structure risk-sharing mechanisms
- pilot high-risk projects with partial guarantees
- showcase successful projects to build trust among investors.

Involved actors:

- EU Commission, financial institutions, insurers, renewable energy developers.

Why is this recommendation important:

- addresses perceived risks, unlocking capital for innovative projects.

Expected benefits:

- increased investment in cutting-edge technologies
- accelerated adoption of high-impact renewable solutions
- broader participation from private investors.

6.3.3 Market recommendations

6.3.3.1 Development of national pilot programs for blockchain applications

Barrier addressed:

- Lack of Similar Case Studies in the EU Using Blockchain.

Definition of the recommendation:

- launch pilot projects at the national level to explore blockchain's potential in energy trading, P2P transactions, and demand-side management.

Actions that needed to be taken:

- fund pilot programs through national energy transition funds
- partner with local universities and energy companies to design and implement projects
- publish case studies and best practices from pilot results.

Level of application:

- Member State funding and implementation.

How to implement recommendation:

- identify key use cases (e.g., P2P trading, energy communities)
- form public-private partnerships to pool resources
- use regional energy platforms for experimentation.

Involved Actors:

- national energy ministries, local utilities, blockchain developers, universities.

Why is this recommendation important:

- demonstrates blockchain feasibility, builds trust, and informs policy frameworks.

Expected benefits:

- increased local adoption of blockchain solutions
- enhanced stakeholder confidence and market innovation
- data to support national and EU policy alignment.

6.3.3.2 Establishment of rules for aggregating offers and bids

Barrier addressed:

- Possibility of using aggregated offers and bids.

Definition of the recommendation:

- create regulatory provisions that allow aggregators to combine small-scale energy resources (e.g., EV chargers, batteries) into single offers for local energy markets.

Actions that needed to be taken:

- define aggregation rules for participation in local markets
- incentivize businesses to adopt aggregation technologies
- develop pilot aggregation projects in select regions.

Level of application:

- Member State regulations for local markets.

How to implement recommendation:

- collaborate with local utilities and grid operators
- run regional pilots to refine aggregation models
- publish standard operating guidelines for aggregators.

Involved actors:

- national regulators, local energy companies, aggregators, technology providers.

Why is this recommendation important:

- unlocks the potential of distributed resources for grid stability and market participation.

Expected benefits:

- increased market participation of small-scale energy resources
- improved grid reliability and renewable energy integration
- reduced consumer energy costs.

6.3.3.3 Development of market access frameworks for smart technologies

Barrier addressed:

- Insufficient Market Access for Smart Services and Technologies.

Definition of the recommendation:

- create clear pathways for integrating smart technologies (e.g., demand response, smart meters) into local energy markets.

Actions that needed to be taken:

- simplify procedures for certifying and integrating smart technologies
- mandate local utilities to adopt smart systems for grid management
- provide subsidies for smart technology adoption by consumers.

Level of application:

- Member State-level energy market regulations.

How to implement recommendation:

- develop national standards for smart technology compatibility
- fund technology adoption through national energy transition programs
- collaborate with local governments for implementation in municipalities.

Involved actors:

- national energy ministries, local regulators, smart technology providers.

Why is this recommendation important:

- encourages innovation and ensures smooth integration of advanced technologies into local energy markets.

Expected benefits:

- increased adoption of smart systems
- higher energy efficiency and consumer participation
- enhanced grid modernization and resilience.

6.3.3.4 Harmonization of market rules on the national level

Barrier addressed:

- Fragmented Market Rules for Energy Trading.

Definition of the recommendation:

- standardize rules for energy trading within the Member State to simplify participation and align regional markets.

Actions that needed to be taken:

- align market regulations across regions within the Member State
- develop common procedures for feed-in tariffs and P2P trading
- create a unified regulatory body to oversee compliance.

Level of application:

- national-level coordination across regions.

How to implement recommendation:

- establish working groups with regional governments and utilities
- use pilot programs to test rule harmonization
- regularly update rules based on feedback and outcomes.

Involved actors:

- national governments, regional authorities, local energy regulators.

Why is this recommendation important:

- reduces inefficiencies, promotes fairness, and encourages cross-regional energy collaboration.

Expected benefits:

- streamlined market operations
- increased investment and participation
- enhanced regional cooperation.

6.3.3.5 Running awareness campaign for consumers

Barrier addressed:

- Limited Consumer Awareness and Participation.

Definition of the recommendation:

- educate consumers on energy market opportunities, including dynamic pricing, demand response programs, and P2P trading.

Actions that needed to be taken:

- develop national-level campaigns to promote awareness of smart energy options
- use digital tools (e.g., apps, websites) to engage consumers
- partner with local governments and NGOs for on-ground outreach.

Level of application:

- Member State campaigns at the local level.

How to implement recommendation:

- create user-friendly materials in multiple languages
- launch educational initiatives in schools and community centres
- offer financial incentives for participation in pilot programs.

Involved actors:

- national governments, local authorities, consumer advocacy groups, energy companies.

Why is this recommendation important:

- boosts consumer engagement, reduces barriers to participation, and drives the adoption of renewable energy and smart systems.

Expected benefits:

- increased consumer participation and energy literacy
- higher adoption rates for smart technologies
- reduced energy costs and increased demand-side flexibility.

6.3.4 Recommendations per Business Cases

Based on identified barriers within each Business Case, a set of recommendation per BC is given in the Figure 2.

Figure 2 Barriers and recommendations in Business Cases

	Barrier	BC1	BC2	BC3	BC4	BC5	Recommendation
Regulatory	Regulatory barriers to grid integration of renewable energy and distributed energy resources (DER)	⚡	⚡		⚡	⚡	Standardization of grid integration frameworks for renewables and distributed energy sources
	Data privacy and energy data regulations	⚡	⚡	⚡	⚡	⚡	Development of GDPR-Compliant Energy Data Platforms
	Lack of regulatory support for energy communities		⚡			⚡	Providing consistent support for energy communities
	Building regulations and energy-efficient retrofitting			⚡		⚡	Update of building regulations to mandate energy efficiency retrofits
	Regulatory gaps in demand response participation and consumer flexibility compensation				⚡	⚡	Enabling Demand Response and Consumer Compensation Mechanisms
	Virtual power plant (VPP) regulations					⚡	Clarification of regulations for Virtual Power Plants
	Transition policies for natural gas systems			⚡			Balancing natural gas transition policies
Financial	Limited access to financing for renewable energy and DER projects	⚡	⚡			⚡	Creation of National Green Energy Funds
	High upfront costs of energy efficiency and retrofitting projects			⚡	⚡	⚡	Development of targeted subsidies and loan programs for retrofitting
	Lack of standardized financial models and incentives	⚡	⚡			⚡	Standardization of renewable energy incentives
	Insufficient monetization mechanisms for demand flexibility				⚡	⚡	Monetization of demand flexibility with dynamic pricing
	Regulatory complexity in accessing public or EU funds	⚡	⚡			⚡	Simplification of the access to state and public funds
	Risk aversion among financial institutions	⚡	⚡			⚡	Launch of risk-sharing mechanisms for high-risk projects
Market	Lack of similar case studies in the EU using blockchain	⚡	⚡	⚡	⚡	⚡	Development of national pilot programs for blockchain applications
	Possibility of using aggregated offers and bids				⚡	⚡	Establishment of rules for aggregating offers and bids
	Insufficient market access for smart services and technologies				⚡	⚡	Development of market access frameworks for smart technologies
	Fragmented market rules for energy trading	⚡	⚡			⚡	Harmonization of market rules on the national level
	Limited consumer awareness and participation	⚡	⚡		⚡		Running awareness campaign for consumers

7 Roadmap on identification and prioritisation of viable smart services and technologies that connect energy sectors and energy carriers

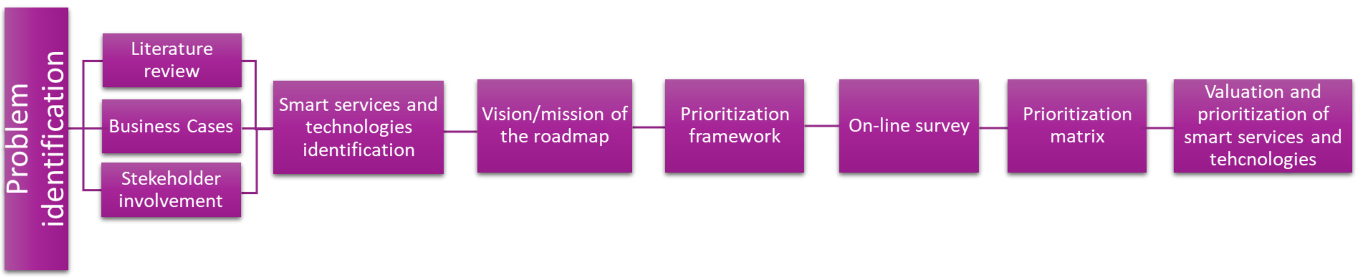
7.1 InEExS approach

This chapter presents the roadmap methodology, combining literature analysis, known practices (Business Cases), and knowledge about innovative smart energy services and technologies, that emerged from the InEExS project. Firstly, legislative documents on the EU level, such as Energy Efficiency Directive (2023/1791 EU) and Electricity Directive (2019/911) were identified and served as a basis for identification of smart services and technologies that connect energy sectors and energy carriers. Moreover, a literature review, using keywords such as “smart service, smart technologies, prioritization, energy efficiency, identification, blockchain, electricity”, was conducted, using the most recent publications, from 2020 onwards.

Secondly, Business Cases (BCs), developed under the InEExS project, were thoroughly analysed and reviewed in several papers that came out from this project but are also included in this paper to familiarize the public with BCs. Out of BCs, the most important smart services and technologies were extracted and analysed, based on the abovementioned literature reviews.

The third step was the prioritisation process which involved several phases. In the first phase, a prioritisation framework was established, based on literature and data extracted from Business cases. With a pre-determined prioritisation framework, the second phase involved the conduction of an online survey with key information about each prioritization criterion to help in the evaluation of smart services and technologies (1 to 5 Linear numeric scale). The online surveys were administered to InEExS project partners and sent via e-mail. The third phase was a detailed analysis of the survey results and the prioritization process which involved a ranking process of Likert Scale using median value.

Figure 3 Methodology of the Roadmap



7.2 Prioritisation of smart services and technologies

After the identification and brief analysis of each smart service or technology (see chapter 5.2), the next phase is the prioritisation of these services and technologies, in accordance with the criteria specified in Annex 1 of this document. Prioritization was made in order to see what smart services and technologies are the most feasible to implement. By prioritizing, Business Case leaders and various stakeholders can create a structured pathway for deploying smart services and technologies that meet energy transition objectives efficiently and effectively.

Considering that prioritisation is a very subjective method, research was done in the form of an online survey, sent via e-mail to all InEExS project partners to rank each of the smart services and technologies according to each given criterion with scores from 1 to 5 (Linear numeric scale), 1 indicating the lowest value of relevance of the smart service or technology and 5 the highest value of relevance of the smart service or technology.

The degree of relevancy for each smart service or technology was determined through three levels (low, medium, and high) by evaluating the arithmetic averages as follows: average range from 1.00 to 2.33 represent low relevance, from 2.34 to 3.67 represent medium, and from 3.68 to 5.00 represent high relevance of the criterion for smart service or technology. The scale was calculated by using the following equation: The upper limit of the scale (5) was subtracted from the lower limit of the scale (1), and the result was (4). Then, the difference between the two terms was divided into three levels (4/3), and the result was 1.33. Finally, the answer (1.33) was added to the end of each category [61].

The prioritisation matrix, based on the results of the survey is given below in Table 5.

Table 5 Prioritization matrix

SMART ENERGY SERVICES PRIORITISATION MATRIX

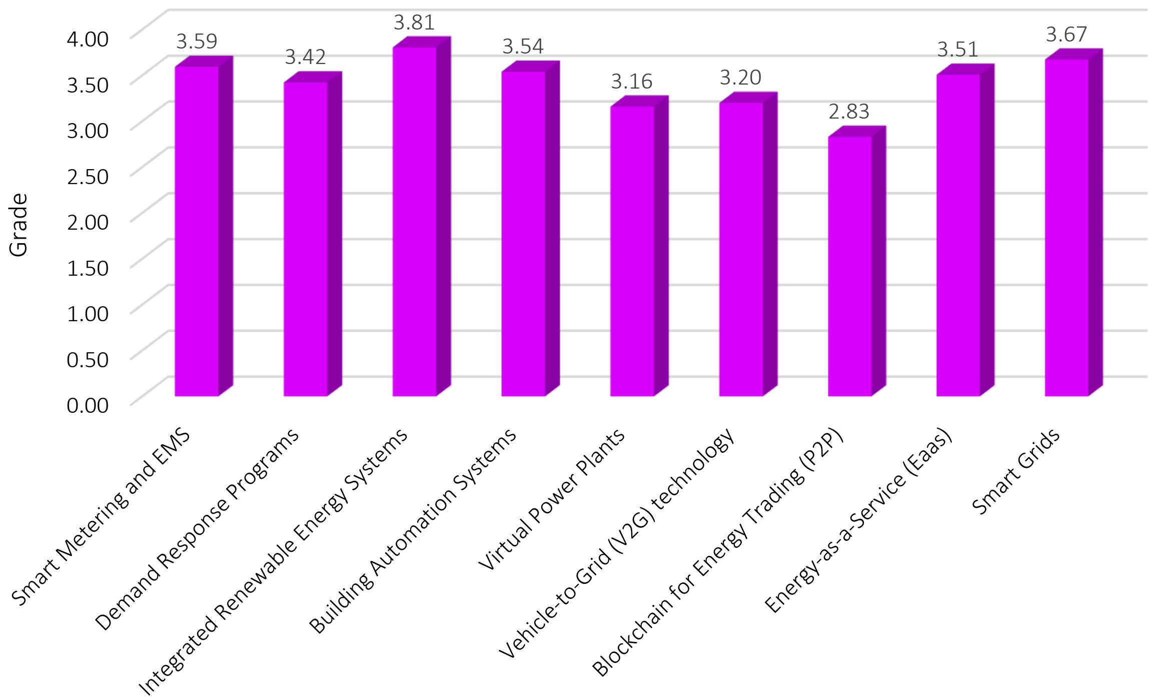
InEExS ENERGY SERVICES ON THE BLOCKCHAIN

High Relevance | Medium Relevance | Low Relevance

	Sustainability impact	Energy efficiency	Technological maturity	Ease of implementation	Integration Capability	ROI	Scalability	Cross-sector demand	Value proposition	User friendliness	Cross-sector compatibility	Standardization	Data protection	Technological Advancement	Alignment with Future Trends
Smart Metering + EMS	High	High	High	Medium	Medium	Medium	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium	High
Demand Response Programs	High	High	Medium	Medium	Medium	Medium	Medium	Medium	High	Medium	Medium	Medium	Medium	Medium	High
Integrated Renewable Energy Systems	High	High	High	Medium	Medium	Medium	High	High	High	Medium	Medium	Medium	Medium	High	Medium
Building Automation Systems	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High
Virtual power plants	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High
V2G Technology	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High
Blockchain for Energy Trading	Medium	Medium	Medium	Low	Medium	Medium	Medium	Medium	Medium	Low	Medium	Medium	Medium	Medium	Medium
Energy as a service	High	High	Medium	Medium	Medium	Medium	Medium	Medium	High	Medium	High	Medium	Medium	High	High
Smart Grids	High	High	Medium	Medium	Medium	High	High	High	Medium	Medium	High	Medium	Medium	High	High

To prioritise smart services and technologies according to their relevance, an average grade for each smart service and technology for sector integration was calculated. Based on that, smart services and technologies are prioritized as follows in Figure 4.

Figure 4 Average grade of each smart service and technology



The results of the Figure 4, or its ratings, are correlated with the smart services and technologies so that those with higher ratings – such as smart grids, IRES, EVs, smart metering and EMS – are utilized more often in the Business Cases. However, since they are more frequently used in BCs, that can explain their higher grades in the prioritization.

8 Conclusions and next steps

This report presents a detailed roadmap for addressing the barriers that hinder the implementation of smart services and technologies in innovative energy business models. By focusing on regulatory, financial, and market-specific challenges, it outlines roles and responsibilities for key stakeholders, including policymakers, national authorities, energy service providers, technology developers, and others. The findings and recommendations aim to align efforts with European objectives such as the Green Deal and the Fit-for-55 package.

National authorities, including energy regulators, energy agencies, and local governments, are key to addressing regulatory challenges. Fragmented policies, inconsistent permitting procedures, and insufficient data protection frameworks present significant obstacles to scaling smart services and technologies. Authorities should work towards harmonising regulations across Member States, introducing standardised approval processes, and ensuring secure and compliant integration of blockchain technologies. These efforts can enhance the feasibility of projects like the Decentralised Energy Efficiency Power Plant (DEEPP, BC5). In addition, national authorities should engage in capacity-building initiatives to improve awareness of smart services and technologies and support the involvement of local governments, utilities, and consumers.

Energy service providers, such as utilities, grid operators, energy cooperatives, and ESCOs, must focus on implementing business models that are tailored to specific market needs. For instance, improved self-consumption of Distributed Energy Resources (DERs, BC2) in energy cooperatives can benefit from blockchain-based tokenisation to enhance consumer participation. Similarly, smart energy management systems for EV charging and HVAC appliances (BC4) can reduce costs while supporting grid operators. Providers should also invest in consumer-focused applications that promote energy efficiency and increase user engagement.

Technology developers, including ICT experts, device manufacturers, and blockchain specialists, are essential in addressing technical and operational challenges. Interoperability must be a priority, particularly for IoT-enabled devices used in models like Energy Efficiency and Flexibility Services for Legacy Natural Gas Boilers (BC3). Blockchain applications in Improved Self-Consumption of DERs in Energy Cooperatives (BC2) must ensure compliance with GDPR while maintaining user trust. Developers should also collaborate with energy providers and regulators to align their innovations with market needs and regulatory requirements.

National authorities and energy agencies can support these efforts by simplifying administrative requirements and offering financial incentives. They can promote public-private partnerships and alternative financing mechanisms, such as green bonds and energy-as-a-service models, to lower the financial barriers to implementing smart services and technologies. These agencies can also facilitate knowledge-sharing among stakeholders and drive replication of successful initiatives.

The implementation of smart services and technologies requires a coordinated approach from all stakeholders. Policymakers must establish clear and consistent regulatory frameworks that support innovation. Energy service providers should adopt models that address user needs and ensure effective delivery of services. Technology developers must focus on creating reliable and user-friendly solutions. National authorities and energy agencies should provide the structural and financial support necessary to overcome barriers and enable widespread adoption.

Validation of the proposed strategies through real-world testing is essential. The Business Cases outlined in this report provide opportunities to refine and demonstrate the effectiveness of these models. For example, dynamic tariffs can be tested to improve PV self-consumption in Recommendations for Innovative Energy Contracts with Pay-for-Performance Guarantees (BC1). Blockchain-based peer-to-peer energy trading in Improved Self-Consumption of DERs in Energy Cooperatives (BC2) and IoT-driven upgrades for legacy natural gas boilers in Energy Efficiency and Flexibility Services for Legacy Natural Gas Boilers (BC3) offer opportunities to demonstrate their feasibility and scalability.

The integration of smart services offers significant opportunities to optimise energy management, reduce greenhouse gas emissions, and improve consumer engagement. By addressing the barriers outlined in this report, stakeholders can work together to drive meaningful progress towards the EU’s energy and climate goals. These efforts will support a more efficient energy sector and contribute to a future-ready energy system.

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Annex I

Prioritisation criteria

1. **Sustainability impact:** refers to a smart service or technology's ability to meet society's current needs without harming or compromising the future, in economic, environmental, and social dimensions. (1 - smart services and technologies do not enhance sustainability, 5 - smart services and technologies highly enhance sustainability)
2. **Energy efficiency:** refers to services or technologies that improve energy efficiency and reduce overall consumption (1 - very low impact on energy efficiency, 5 - very high impact on energy efficiency)
3. **Technological maturity:** refers to a stage of smart service or technologies where most of its initial faults and inherent problems have been removed or reduced by further development. (1 - technologically not mature, 5 - technologically very mature)
4. **Ease of implementation:** refers to how easy it is to implement smart service or technology to carry out a desired process. (1 - difficult to implement, 5 - easy to implement)
5. **Integration Capability:** refers to the ease of integrating smart services or technologies within existing infrastructure across different sectors and energy carriers (1 - low integration capability, 5 - high integration capability)
6. **ROI:** refers to Return of Investment, an approximate measure of smart service or technology's profitability. It is calculated by dividing the profit earned on an investment by the cost of that investment (1 - very long, 5 - very short)
7. **Scalability:** the ability of the smart service or technology to grow larger or can be scaled up (used in larger facilities or by a larger number of consumers) (1 - smart service or technology can not be scaled up, 5 - smart service or technology can be scaled up easily)
8. **Cross-sector demand**: refers to a smart service or technologa that demands to be used in multiple sectors or connect them. (1 - no cross-sector demand, 5 - high cross-sector demand)
9. **Value proposition**: refers to the ability of smart service or technology to bring benefits to consumers and businesses, including cost savings, increased efficiency, and enhanced reliability (1 - no value proposition, 5 - very high-value proposition)
10. **User-friendliness**: refers to ease of use and adoption by consumers and businesses (1 - not user-friendly, 5 - very user-friendly)

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11. **Cross-sector compatibility**: refers to how well the service or technology can integrate across different sectors and energy carriers (1 - not compatible, 5 - very compatible)
12. **Standardization**: refers to how easily the service or technology adheres to industry standards for interoperability (1 - very difficult adherence, 5 - very easy adherence)
13. **Data protection**: refers to the smart services or technologies that have robust data security measures (1 - low-security measures, 5 - high-security measures)
14. **Technological Advancement**: refers to whether smart services or technologies use cutting-edge technologies (1 - low technological advancement, 5- high technological advancement)
15. **Alignment with Future Trends**: refers to whether smart services or technologies align with future market trends and technological developments (1- low alignment, 5 - high alignment).

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