Smart2B
Smartness to existing Buildings

UPGRADING SMARTNESS OF EXISTING BUILDINGS THROUGH INNOVATIONS FOR LEGACY EQUIPMENT

Deliverable 7.3

Smart Building Market Report

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Executive Summary

The deliverable D7.3 "Smart Building Market Impact Assessment" is associated with Task T7.3 in WP7, which focuses on the commercial scale-up of Smart2B innovations. This deliverable aims to analyze the smart building market, evaluating prominent manufacturers, assessing market penetration, and developing market scenarios to project the impact and penetration of Smart2B solutions.

The objective of this deliverable is to provide a comprehensive market assessment of smart building technologies, including Building Energy Management Systems (BEMS) and flexibility solutions. The deliverable includes a detailed analysis of leading manufacturers, categorizing them based on their value propositions, functionalities, and market strategies. Additionally, it evaluates the Smart Readiness Indicator (SRI) of buildings in different EU member states to identify suitable markets for Smart2B solutions.

This deliverable comprises several key sections, including:

- Smart Technologies Market Assessment: An in-depth analysis of the smart technologies market, focusing on recent trends, growth determinants, and the competitive landscape.
- Prominent BEMS Manufacturers Evaluation: This section highlights each manufacturer's unique selling propositions, market focus, technological advancements, and strategic initiatives. Afterwards, a comprehensive assessment framework is created that compares various manufacturers, identifying market saturation and potential opportunities. This part evaluates manufacturers on multiple dimensions, providing insights into their strengths and weaknesses.
- Flexibility Market Evaluation: This section offers an analysis of the flexibility market, focusing on key manufacturers and their services. It includes a detailed examination of companies providing flexibilty services within Europe. The assessment covers their market focus, technological advancements, and strategic initiatives. In this regard, a comprehensive assessment framework is conducted for evaluating flexibility solutions providers.
- SRI Assessment of the EU Market: Application of the SRI methodology to evaluate the smart readiness of residential and non-residential buildings across different EU member states. This section identifies suitable markets for Smart2B solutions based on SRI scores.
- Market Scenarios Development: Creation of market scenarios that will feed in the work under the task 7.4 using cost-benefit assessment (CBA) indicators.These scenarios provide a foundation for strategic planning and market entry, projecting Smart2B's market penetration and economic viability.

By analyzing competitors and market conditions, this deliverable aids in strategic decision-making for the commercial scale-up of Smart2B innovations. It outlines the path to position Smart2B in the EU market and emphasizes the importance of the keyservices that address the existing market gap for the overall exploitation of the Smart2B platform. The deliverable thus provides a comprehensive overview of the competitive landscape and potential market scenarios for smart energy products and services.

1. Introduction

The Smart2B project aims to develop a versatile system that enhances the smartness level of various building types in the residential as well as in the non-residential building sector. This system is designed to improve energy consumption and efficiency of existing buildings, distinguishing itself from other Building Energy Management Systems (BEMS) that are often limited to specific building types and primarily focus on new equipment. Smart2B's holistic approach includes the capability to control legacy equipment and manage every energy-related aspect of a building, making it a unique and innovative solution in the BEMS market. By offering a comprehensive platform that integrates efficiency, comfort, health, energy flexibility, user engagement, and predictive degradation algorithms, Smart2B aims to deliver disruptive innovation and a superior value proposition (VP) compared to current market offerings. The deliverable encapsulates the activities and outcomes of Task 7.3, led by RWTH Aachen University, focusing on the commercial scale-up of Smart2B innovations. The task comprises the three sub-tasks of competitor analysis, SRI-market evaluation and the development of different market scenarios in order to verify the assumptions of SMART2B's anticipated market penetration.

A detailed analysis was conducted on manufacturers and products within the smart energy sector throughout **section 2 and 3**, categorizing competitors based on their value propositions. An assessment matrix was developed to gather and organize data from relevant BEMS and flexibility competitors and applied to approximately 30 manufacturers. Products are evaluated across different categories, including their impact on energy efficiency, comfort, maintenance, and grid-interaction. Market penetration, business models, value proposition and marketing and investment strategies are other parameters by which competitors are evaluated. Two SWOT analyses for the BEMS and flexibility market are conducted to identify the existing trends and gaps in both markets.

The subtask of SRI-market evaluation in **section 4** applies the SRI methodology to residential and non-residential buildings in the EU to evaluate the smart readiness of the building stock across different EU member states and identify suitable markets. A detailed questionnaire covering the nine technical domains of SRI calculation was designed to gather data from in seven different EU countries. The resulting SRI scores reflect the readiness of buildings in different regions, providing crucial insights for market entry strategies.

Several market scenarios are developed in **section 5** using cost-benefit assessment (CBA) indicators, considering factors such as electricity prices, CO_2 taxes, feed-in tariffs, flexibility services, and energy savings from renovations. These scenarios aim to provide a robust foundation for strategic planning and market entry, projecting Smart2B's market penetration and evaluating the economic viability of the proposed solutions. The developed market scenarios serve as a basis for the quantification of Smart2B's impact on the European building stock during the Smart2B project.

By meticulously analysing competitors and market conditions, the deliverable aids in strategic decision-making for the commercial scale-up of Smart2B innovations. It outlines the path to assess KERs groups, the value they demonstrate in Smart2B pilots, and their importance for the overall exploitation of the Smart2B platform. The deliverable thus provides a comprehensive overview of the competitive landscape and potential market scenarios for smart energy products and services.

2. Smart technologies market assessment

This chapter provides a comprehensive analysis of the smart technologies market, with a particular emphasis on recent trends, growth determinants, and the competitive landscape. It examines various segments within the smart home solutions domain, including HVAC control systems, smart thermostats, and advanced energy management technologies. The assessment evaluates how leading manufacturers are innovating and positioning their products to address the dynamic needs of both consumers and commercial entities.

2.1. Overview of prominent manufacturers

This section offers an in-depth overview of key manufacturers within the smart technologies sector, focusing on their flagship products, market strategies, and technological innovations. It includes detailed examinations of companies such as Bosch, BeeBryte, DABBEL, Homix, Johnson Controls, MeteoViva, R8 Technologies, and Shelly. The discussion highlights each manufacturer's unique selling propositions, market focus, technological advancements, and strategic initiatives aimed at enhancing energy efficiency, user comfort, and sustainability in both residential and commercial building applications.

2.1.1. Bosch Room Thermostat

Bosch, a company renowned for its technological advancements, has introduced two innovative **smart room thermostats**: the Room Thermostat II and the Room Thermostat II 230 V. Despite their similar nomenclature, the critical distinction between the two lies in the inclusion of a 230 V power supply in the latter, which significantly impacts their functionality. The development and manufacturing of both the Smart Room Thermostat II and the Smart Room Thermostat II 230 V are overseen by Bosch Smart Home GmbH. Established in 2016, this subsidiary operates as a wholly owned entity under the Robert Bosch GmbH umbrella. This strategic organizational structure underscores Bosch's commitment to pioneering innovation and delivering high-quality home automation solutions. [1]

The smart room thermostats have a targeted presence, primarily catering to European markets. Bosch extends its technological prowess to a select group of European countries, including Austria, Belgium, Denmark, France, Finland, Germany, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland. This strategic focus highlights Bosch's meticulous approach to regional market accessibility [2].

The *Room Thermostat II 230V* is engineered for wired systems, serving as a direct replacement for outdated wired thermostats commonly found in underfloor heating or gas boiler systems. Notably, it necessitates an electric power supply, and in functionality, closely mirrors traditional thermostats. The wiring of the heating system is seamlessly connected directly to the Room Thermostat II 230V, emulating the conventional thermostat model, thereby affording a seamless transition to contemporary climate control technology.

Figure 1: Bosch Room Thermostat II 230V [3]

In stark contrast, the Room Thermostat II functions solely as an external temperature sensor, introducing a novel dimension to Bosch's suite of Smart Radiator thermostats. Unlike its counterpart, it does not directly connect to the heating system nor issue control commands. Instead, its primary function is to gather environmental data, specifically temperature and humidity, which it then transmits to the Smart Home Controller. This controller, a crucial component of the ecosystem, utilizes the data to dynamically generate optimized control directives for Smart Radiator thermostats, thereby enhancing the efficiency of climate control within the smart home.

Essentially, the Room Thermostat II acts as a sophisticated data sensor, streamlining the operations of Smart Radiator thermostats. This innovative functionality addresses a common issue with Radiator thermostats, which are often placed near room peripheries, leading to inaccurate temperature readings due to proximity to walls. The wireless connectivity of the Room Thermostat II allows for flexible placement anywhere in the room, ensuring more precise temperature measurements and improving overall climate control accuracy. [4]

Functionalities

The Room Thermostat II 230 V offers the common functionalities of smart thermostats:

- **Scheduling**: Users can establish personalized heating schedules, tailoring climate control to their preferences. This feature facilitates the optimization of energy consumption.
- **Manual and Remote Control**: The thermostat offers both manual controls, allowing immediate adjustments, and remote control via a dedicated app. This remote accessibility empowers users to manage their home's temperature from virtually anywhere.
- **Voice Control**: Voice commands provide a hands-free approach to adjusting settings, enhancing user convenience.
- **Real-Time Information**: The thermostat provides real-time temperature information, allowing users to stay informed about their home's climate conditions.
- **Open Window Detection**: The device can detect open windows, a crucial feature for preventing energy waste when windows are left ajar. However, it is important to note that this function requires an additional sensor for operation.

- **Child Lock**: For enhanced safety, the thermostat includes a child lock feature, preventing unintended changes to settings.

What sets the Room Thermostat II 230V apart from competitors is its *integrated air quality sensor* and a dedicated control app. The app empowers users to create intricate *automations* based on conditional rules, following the "if-then" logic. For example, users can program the thermostat to automatically close window blinds when a specific room temperature is reached. Additionally, it allows users to activate air humidifiers when humidity levels drop below a predefined threshold. This amalgamation of air quality monitoring and rule-based automation enhances comfort and promotes energy efficiency [5].

However, the Room Thermostat II 230V has some notable limitations:

- **Limited Weather Integration**: The thermostat does not consider external weather conditions when adjusting settings. As a result, it may not provide the most energy-efficient responses to changing weather patterns.
- **Lack of Geofencing**: Geofencing, a feature that enables the thermostat to modify settings based on the user's proximity to their home, is not supported. This could be considered a drawback for those who prioritize energy savings.
- **No Historical Data Access**: Presently, the thermostat does not offer access to historical usage data. This feature, available in some competitor products, can provide valuable insights into consumption patterns [6].

Marketing and Investment topics

Bosch's Room thermostat is a testament to their strategic approach, emphasizing simplicity and core functionalities. Their primary goal is to offer a straightforward, compact solution that caters to basic needs rather than inundating customers with complex features. Their strategy revolves around creating products that are synonymous with reliability, trustworthiness, and universal appeal.

The key highlights of Bosch’s strategy include:

Compatibility and Ecosystem: Bosch's strength lies in the vast smart home ecosystem they've developed. Their products are designed to seamlessly integrate and work in harmony with one another, all accessible through a unified app. They don't merely sell individual smart home devices; they market entire systems that are both easy to use and compatible.

Data Security: Bosch prioritizes data security and privacy. They assure customers that data is stored locally within the smart home controller, communication is encrypted, and independent testing centers verify their products' adherence to rigorous safety standards.

Core Values: Bosch openly expresses their commitment to core values that include compatibility, simplicity, and reliability, which are central to their product offerings [7].

Customer Loyalty: Bosch seeks to build strong customer loyalty and trust. As an incentive, they offer a 20€ voucher to customers who sign up for their newsletter, aiming to nurture lasting relationships [8].

Market Focus: The German market stands as Bosch's largest market. This is evident in their German website, which provides more comprehensive information and features, including a blog not found on other language websites.

Partnership Expansion: Bosch continually expands its partner network to enhance the compatibility of third-party products with their smart home system, demonstrating their commitment to fostering a broader smart home ecosystem [9].

To conclude, Bosch's strategy is rooted in simplicity, reliability, and an unwavering focus on customer satisfaction. By creating a robust, interconnected ecosystem and prioritizing data security, they position themselves as a trusted and user-friendly provider in the smart home industry.

2.1.2. BeeBryte

BeeBryte, founded in 2015, is headquartered in Lyon, France, with additional offices in Rennes, France, and Singapore. The company strategically serves the European and Asian HVAC and refrigeration market. With a team of 51 employees, BeeBryte specializes in the optimization of commercial and industrial buildings, particularly those with large floor areas. These include logistic warehouses, cold storage facilities, office towers, laboratories, shopping centers, and university campuses. The company has a notable presence in industrial refrigeration and commercial cooling, catering to applications like cold storage warehouses, laboratories, and large-scale cooling systems for office towers [10].

BeeBryte's business model operates as a software-as-a-service (SaaS), offering AI-based software for HVAC and refrigeration control. They install a 4G IoT Gateway on-site, facilitating integration with the building management system. This gateway communicates with BeeBryte's cloud computing platform to calculate predictive controls for HVAC and refrigeration systems. By leveraging AI and forecasting changes in weather, business activity, and occupation patterns, BeeBryte anticipates a building's thermal needs. It autonomously adjusts critical parameters in real time, such as chilled water temperature or pump speed, resulting in energy-efficient control of HVAC and refrigeration systems [11].

BeeBryte asserts significant energy cost savings of up to 40%. Notably, the extent of these savings is closely tied to the energy consumption profile of the building. By prioritizing energy efficiency, BeeBryte aims to promote both environmentally responsible practices and cost reduction for its clients [12].

BeeBryte's reputation for efficacy is exemplified by its prestigious clientele, including global corporations such as DHL, Metro, Intermarché, Continental, and Decathlon. These well-known companies entrust BeeBryte with the implementation of smart energy management solutions [13].

Functionalities

BeeBryte employs cutting-edge AI algorithms as the backbone of its operations, enabling it to proactively learn and predict variations in business activity and occupancy patterns within commercial buildings. For instance, it discerns the oscillating foot traffic in shopping malls throughout the day and the fluctuating business activity within logistics warehouses. Additionally, BeeBryte factors in weather forecasts. This rich tapestry of data forms the basis for its AI-driven cloud computing platform, which ultimately generates energy-efficient directives for the building's HVAC system.

BeeBryte prides itself on compatibility, boasting support for a wide array of standard communication protocols such as BACnet, Modbus, and LON. This compatibility ensures seamless integration with most conventional control systems, enhancing the adaptability of its services.

However, BeeBryte's capabilities transcend mere anticipation. The system operates as a vigilant 24/7 watchdog over the HVAC system. Any anomalies and deviations from the expected performance are meticulously monitored. Such discrepancies often serve as early indicators of impending technical failures within the system. Thus, BeeBryte not only optimizes performance but also acts as an early warning system, preventing potential downtimes [11].

One of BeeBryte's key offerings is a customizable dashboard, delivering an elevated level of transparency for operators. This dashboard provides invaluable insights into the operational and energy performance of facilities. Operators benefit from unprecedented data that empowers them to take corrective and preventive actions. The result is twofold: enhanced equipment availability and reduced operating costs, solidifying BeeBryte's commitment to promoting energy efficiency and operational excellence [14].

Marketing and Investment topics

BeeBryte distinguishes itself by marketing its products as *safe and reliable*. They target customers operating sensitive and vulnerable production chains, such as cooling chains or laboratories. Their marketing efforts aim to alleviate concerns about software malfunctions potentially disrupting these critical chains. BeeBryte's message is clear: their system can be installed in a matter of hours without interrupting normal operations. They provide an added layer of confidence by offering insurance to cover any damages resulting from a system malfunction, although they proudly note that their system's reliability has rendered the insurance unnecessary. Additionally, they stress that operators can easily revert to their previous operation mode without BeeBryte's intervention.

BeeBryte adopts a unique cost structure. They do not charge customers for installing the gateway. Instead, their revenue is generated based on a percentage of the achieved energy cost savings. This innovative approach aligns BeeBryte's success with the actual benefits customers experience, fostering a sense of shared interest and trust. BeeBryte's marketing asserts that their solution is suitable for all large-scale HVAC (Heating, Ventilation, and Air Conditioning) systems, regardless of their age or sophistication. They make a compelling case that even the most modern HVAC hardware can often operate inefficiently due to the limited logic programmed into them. BeeBryte focuses solely on optimizing the control commands of existing HVAC systems, leaving the hardware untouched. This approach aims to enhance energy efficiency regardless of the hardware's innate efficiency [11].

BeeBryte secured significant funding of $11.5 million in July 2022. This funding was earmarked to continue the development of their patented predictive control solution for industrial cooling and heating systems, showcasing investor confidence in their innovative approach and growth potential. Their strategic focus on safety, reliability, a unique cost structure, and broad applicability within the cooling and refrigeration sector positions them as a trusted and forward-thinking player in the industry, with significant investment to further drive their mission.

2.1.3. Dabbel

DABBEL, a relatively young start-up, was established in 2018, with its headquarters located in Düsseldorf, Germany. Despite its recent inception, DABBEL has grown to a modest size, employing approximately 20 individuals [15]. DABBEL exclusively offers a single product—an AI-based HVAC control system designed for application in commercial buildings, primarily offices and real estate properties. The core function of this product involves integration with a building's management system, enabling it to orchestrate and optimize the building's HVAC system based on sophisticated AI models [16].

Currently, DABBEL extends its operations to 12 countries, including the USA, UK, Netherlands, Germany, Switzerland, Austria, Slovakia, Poland, the United Arab Emirates, China, Australia, and New Zealand. This geographic expansion underscores DABBEL's commitment to providing their innovative solution on a global scale [17]. DABBEL boldly asserts the potential for remarkable energy savings in HVAC systems within commercial buildings. Their solution purports to achieve savings of up to 40% on energy consumption, with an average energy reduction of 26% per building. In addition to economic benefits, DABBEL is motivated by an ambitious goal—to develop a highly scalable, cost-efficient, and sustainable software solution that contributes to the decarbonization of commercial buildings worldwide. The aspiration is to accelerate this decarbonization process expediently [17], [18].

DABBEL operates on a subscription-based business model. Once their software is installed, customers commit to a monthly subscription fee in exchange for access to and usage of the DABBEL software. This approach ensures an ongoing partnership with customers while generating consistent revenue for the company [19].

Functionalities

DABBEL presents an innovative approach to enhancing the operation of HVAC systems within commercial buildings. The core functionalities of DABBEL, as described in Deal-Magazine, promise a transformative impact on the management of building climate control systems [20].

DABBEL seamlessly integrates with a building's management system, leveraging the power of artificial intelligence (AI) to govern the HVAC system efficiently. This AI-driven approach not only supports manual HVAC control but also assumes responsibility for a range of tasks typically managed by human facility managers. This automation streamlines operations and enhances energy efficiency within the building.

Upon connecting to the building management system, DABBEL diligently identifies linked devices and initiates an in-depth analysis of the building's data. An intrinsic self-learning AI model comes into play, diligently absorbing user behaviour patterns and comprehending the thermal dynamics of diverse rooms and building sections. By assimilating data relating to user behaviour, building thermal characteristics, and real-time weather conditions, DABBEL's AI masterminds predictive commands to govern the HVAC system with optimal energy efficiency.

One notable claim by DABBEL is its capacity to autonomously forecast temperature variations and subsequently optimize building controls, ultimately resulting in improved air quality and user comfort. The AI's precise maintenance of temperature levels surpasses the capabilities of manually controlled HVAC systems, elevating the well-being of building occupants.

DABBEL's vigilance extends to continuous monitoring of HVAC system performance, with real-time data analysis. It harnesses this data to generate immediate reports on the building's

energy efficiency and carbon emission savings. Moreover, DABBEL excels in detecting anomalies and irregularities, thereby minimizing maintenance expenses, reducing technical failures, and lowering operating costs.

To facilitate users in monitoring, analysing, and controlling their buildings, DABBEL offers the DABBEL-Dashboard, a cloud-based application. This versatile tool boasts the capability to manage multiple buildings within a single unified interface[16].

Marketing and Investment topics

DABBEL, an AI-driven energy efficiency solution, is on a mission to enhance efficiency in HVAC systems and make a significant impact on the market. Their strategic priorities include speeding up implementation, focusing on scalability, expanding partnerships, and differentiating through software-only solutions. Thus, Key Highlights of DABBEL's Strategy include:

Rapid Implementation: One of DABBEL's key objectives is to expedite the setup process for their system in new buildings. Currently taking slightly less than a week, their goal is to reduce this time frame to just a few hours. By streamlining the implementation process, they aim to make their solution even more accessible and user-friendly [21].

Scalability: As a startup, DABBEL is channeling its efforts into optimizing a single product, ensuring it can be flexibly adapted to various use cases and scales. The focus on scalability reflects their goal to establish a broader presence in the market. This is evident in partnerships like E.ON, which anticipates DABBEL's application for homes in the future, underlining their broader market expansion ambitions [19].

Partner Network: DABBEL actively seeks to expand its network of partnerships. They invite potential collaborators to become technology partners, licensed resellers, installation partners, or referral partners. This initiative suggests that DABBEL is determined to reach new markets and customer segments by leveraging various types of partnerships [22].

Software Differentiation: DABBEL stands out in the market by offering a pure software product. Their marketing emphasizes that customers can achieve substantial energy savings and reduce carbon emissions without the need for additional hardware installations. This approach is particularly attractive for commercial clients as it enables them to reach energy and emission reduction goals with minimal hardware updates and effort.

Focus on Real Estate Sector: DABBEL's marketing strategy predominantly targets the commercial real estate sector. Their participation in real estate industry conferences and fairs, such as the Real Estate Trade Fair 2023 in Munich, underscores their commitment to establishing their product within this sector. DABBEL aims to be a significant player in optimizing HVAC systems within the real estate industry [18].

DABBEL's strategic objectives emphasize agility, scalability, and software-driven differentiation in the energy efficiency space, focusing on commercial real estate with an eye on future expansion into other markets.

2.1.4. Homix

Homix, a smart home controller and thermostat, is manufactured by EnelX, a part of the Enel Group. Homix primarily serves as a smart thermostat but also boasts the capability to function as a smart home controller for managing lighting and security devices.

Enel Group engages in a multitude of sectors, including power supply (through Enel Green Power, specializing in solar, wind, geothermal, and hydro power plants), energy distribution (via Enel Grids), technological energy solutions catered to businesses, cities, and residential buildings (offered by EnelX), e-mobility (represented by EnelX Way, which includes charging stations), and energy markets (overseen by Enel Global Energy and Commodity Management, encompassing portfolios and hedging)[23].

HomiX is one of the products offered by EnelX, categorized into three sectors: Residential Solutions, Business Solutions, and City Solutions. EnelX extends its products and services across 18 countries worldwide. These countries include Italy, Spain, Portugal, the United States, Canada, the United Kingdom, Romania, Poland, Ireland, Australia, New Zealand, Japan, South Korea, Brazil, Colombia, Peru, Chile, and Argentina. It's worth noting that the availability of EnelX products may vary from one country to another, encompassing the complete spectrum of Residential Solutions, Business Solutions, and City Solutions.

EnelX's Residential Solutions, to which Homix belongs, are specifically available in a select number of countries. These countries include Romania, Italy, Spain, Portugal, Colombia, Peru, Chile, Argentina, and Brazil[24]. Homix, as a product, is accessible in only three countries—Spain, Italy, and Romania[25].

Functionalities

HomiX, the smart home controller and thermostat manufactured by EnelX, exhibits an array of functionalities that set it apart in the realm of smart thermostats and home automation. These functionalities cater to both heating control and broader smart home management, as detailed below.

HomiX incorporates the core functionalities typical of smart thermostats, prominently offering users the ability to schedule heating times. What distinguishes it from conventional smart thermostats is its deployment of an AI algorithm. This AI-driven technology, as featured in HomiX, learns user habits and autonomously constructs heating schedules tailored to individual preferences. Furthermore, HomiX harnesses geolocation data to dynamically adjust heating schedules based on user proximity, thereby enhancing energy efficiency.

An innovative aspect of HomiX is its capacity to send notifications when family members leave or enter the house. This feature promotes both comfort and energy efficiency by ensuring that heating systems are optimized according to occupancy.

HomiX excels by functioning as a comprehensive Smart Home Controller. In addition to managing heating, it has the ability to control a wide range of smart home products, including lighting systems, smart valves, security devices, and smart sockets. This multifaceted control extends to both existing and expanding lists of compatible smart devices that can be connected to HomiX via a dedicated app. Notably, HomiX offers users the flexibility to customize each connected component according to their preferences and requirements.

HomiX is designed to offer convenience. Users can remotely control HomiX through a dedicated app, enhancing accessibility and usability. Additionally, it seamlessly integrates with voice-activated systems like Amazon's Alexa, thereby providing a hands-free and convenient means of control and interaction[26].

Marketing and Investment topics

EnelX's strategy for their HomiX smart home system, as well as their broader business model, is centered on user-friendliness, accessibility, and strategic partnerships. Here are the key aspects of their marketing and investment approach:

1. User-Friendliness and Accessibility: EnelX emphasizes the user-friendliness of their HomiX smart home system. Their goal is to make smart homes accessible to everyone, including those who may not be technology enthusiasts. They believe that providing value to a broad range of users will lead to quicker adoption by the general public. HomiX offers both ease of use and customization, catering to different user profiles[26].

2. Cost-Efficiency and Budget-Friendliness: EnelX positions HomiX as a more cost-efficient and budget-friendly solution compared to competitors. They aim to make smart home technology accessible to a wider range of consumers by offering competitive pricing and value for money.

3. Business Model - Focus on Private Individuals (B2C): EnelX's business model for HomiX is primarily oriented toward sales to private individuals, aligning with its residential solutions sector. This indicates a strong focus on the consumer market for smart home products.

4. Diversified Portfolio (B2C, B2B, B2G): EnelX offers a diverse portfolio that includes solutions for both the consumer market (B2C) and other sectors such as businesses (B2B) and government (B2G). This diversity covers a wide range of applications, from individual homes to city-wide infrastructure projects like smart public lighting.

5. Strategic Partnerships and Alliances: EnelX is actively investing in partnerships and alliances. Recent press releases in May 2023 announced collaborations with Ferrari, FICEI (projects building energy communities), and the Magaldi Group (project building thermal storages for industrial use). These partnerships aim to better address the specific needs of customers and expand into new markets [27].

6. Home PV and Storage: Enel X combines photovoltaic plants with batteries to produce and store affordable and renewable energy from the sun. Over 15% of the materials used in these systems are recycled, contributing to sustainability.

7. Home Boiler: Enel X's boilers are built with 40% recycled steel, reducing energy consumption and environmental impact by recovering heat from exhaust gases. At the end of their life cycle, over 85% of the steel parts are collected and recycled.

8. Home Air Conditioners: Enel X selects energy-efficient and technologically advanced air conditioning units that maximize comfort and savings. These units align with Circular Economy principles by using sustainable inputs and offering product-as-a-service options.

9. Solar Thermal: Enel X's solar thermal systems directly convert solar power into heat for homes, reducing emissions and costs. Most parts of these systems are recycled at the end of their life cycle, with only a minimal amount of input materials discarded [28].

10. International Reach: Enel X's circular products and solutions have an international presence, serving countries such as Chile, Colombia, Italy, and Spain.

To conclude, EnelX's approach revolves around accessibility, affordability, and customization in the smart home sector. They seek to make smart homes an attainable reality for a broad audience while forging strategic alliances to enhance their offerings.

2.1.5. Johnson Controls (Lux Products)

Johnson Controls, originally founded as the Johnson Electric Service Company in Milwaukee, USA, has a rich history dating back to 1885. Today, the company is headquartered in Cork, Ireland, and operates as a multinational corporation spanning across 150 countries, boasting a workforce of more than 100,000 employees. Johnson Controls positions itself as a global leader in the creation of intelligent, health-conscious, and sustainable buildings [29].

Johnson Controls takes pride in offering a diverse portfolio of products catering to various aspects of building energy management. This extensive range includes solutions for Heating, Ventilation, and Air Conditioning (HVAC), Building Automation and Control Systems (BACS), distributed energy storage, security systems, smart homes, industrial refrigeration, and retail applications. While they have a strong presence in the residential and smart home sector, it's important to note that this domain represents just a fraction of their comprehensive portfolio [30].

The Residential and Smart Homes sector within Johnson Controls offers a variety of products that contribute to the comfort and security of homes. Their offerings encompass heating and cooling solutions like heat pumps, air handlers, air conditioners, and gas furnaces. They are also committed to improving indoor air quality, providing air cleaners, humidifiers, dehumidifiers, and various HVAC components. Moreover, Johnson Controls caters to home security with offerings such as fire and security detectors, as well as keypads. Smart thermostats form a pivotal part of their product range. These smart thermostats are manufactured under the Lux Products brand, which Johnson Controls acquired in October 2018 [31].

Lux Products is the thermostat brand under Johnson Controls, responsible for manufacturing three distinct smart thermostats: KONO, GEO, and CS1. These thermostats can be conveniently controlled via the LUX App, allowing users to manage their home climate with ease. While these three smart thermostats share common functionalities, they offer diverse designs and price points. This description focuses on the KONO smart thermostat, recognized as their most contemporary smart thermostat [32].

Johnson Controls' long-standing history and worldwide presence underscore its authority in the realm of energy management for buildings. The acquisition of Lux Products further enhanced their capabilities, enabling them to provide innovative smart thermostats as part of their comprehensive product line-up [33].

Figure 2: Kono Smart Thermostat [34]

Functionalities

The LUX KONO Smart Thermostat represents an amalgamation of elegant visual design with functionality, striving to enhance the comfort and convenience of home climate control. This academic description delves into the myriad features and capabilities that set the KONO thermostat apart as an efficient and stylish home automation device. The KONO Smart Thermostat provides several features focused on design elegance, customization and smart functionalities to optimize energy efficiency:

Interchangeable User-Definable Design: The KONO Smart Thermostat introduces a unique customization element with its interchangeable Décor-Snap Covers. Eight color options are available. If none of these align with the room's interior, there is also an option to custom-paint the cover.

Smart Scheduling: The KONO thermostat offers essential smart thermostat features, notably including smart scheduling, empowering users to program temperature settings in alignment with their daily routines.

Utility Cost Estimation: The thermostat estimates utility costs and provides comprehensive reports on energy consumption and runtime usage.

Voice Assistant Integration: The KONO thermostat extends compatibility to Amazon Alexa, Apple HomeKit, and the Google Assistant, making voice-activated control seamless.

Home & Away Aware Geofencing: A distinct advantage of the KONO thermostat is its Home & Away Aware geofencing feature, which automatically adjusts temperature settings based on the occupants' presence or absence [35], [36].

Air Quality Enhancement: Setting itself apart from competitors, the KONO Smart Thermostat incorporates a built-in air quality mode, a rarity in the smart thermostat market. This mode enhances indoor air quality, promoting healthier living conditions[37].

Remote Temperature Control: A free control app, known as the LUX Control App, facilitates effortless operation of the KONO Smart Thermostat, as well as other LUX smart thermostats. This app empowers users to remotely monitor and control room temperature, enhancing convenience in climate control. Moreover, it enables users to control multiple thermostats across various locations, ensuring an integrated experience [38]

Energy and Weather Reporting: It includes a menu that reports energy usage, runtime statistics, and provides real-time weather information pertinent to the thermostat's current location.

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Marketing and Investment topics

Lux Products focuses on design and personalization as key marketing strategies for their KONO smart thermostat. The primary distinguishing feature of the KONO smart thermostat is its ability to exchange the front plate, allowing users to customize the design to match their personal preferences and room interior. Lux Products positions the KONO thermostat as the ideal solution for customers who highly value modern design and wish to personalize their thermostat in a way that complements their room's aesthetics [37].

In June 2023, Johnson Controls acquired M&M Carnot, a strategic move to enhance its portfolio in sustainable Industrial Refrigeration. The acquisition aims to meet the increasing demand for natural refrigeration solutions with ultra-low global warming potential. Johnson Controls presents this acquisition as an investment in providing more sustainable products. The company positions itself as actively seeking technological solutions to reduce greenhouse gas emissions and promote sustainability in response to environmental concerns [39].

In April 2023, Johnson Controls and HD Supply announced a strategic national distribution collaboration for residential HVAC (Heating, Ventilation, and Air Conditioning) equipment. This partnership allows Johnson Controls to strengthen its presence and distribution of HVAC equipment in the residential sector, ensuring a wider reach for their products and services [40]. Johnson Controls' strategic investments and collaborations reflect the company's commitment to sustainability and environmental responsibility. They seek to expand their product offerings while addressing environmental challenges and providing sustainable solutions to their customers.

2.1.6. MeteoViva

MeteoViva, a German company with its headquarters in Jülich, has been at the forefront of the smart-data revolution since its inception in 2001. With a global presence that spans across Europe and North America, including Germany, the Netherlands, Belgium, Luxembourg, France, Switzerland, the United Kingdom, and the USA, MeteoViva is committed to redefining the way buildings are managed. Operating from five strategically located offices, including Jülich, Aachen, Capelle aan den Ijssel, Binningen, and Pittsburgh, MeteoViva comprises a dedicated team of 55 employees, as per LinkedIn, who are actively shaping a more sustainable future [41], [42], [43].

At the core of MeteoViva's offerings are two complementary products: MeteoViva Climate and MeteoViva EMS. MeteoViva Climate serves as an intelligent HVAC control system tailored to commercial buildings. In parallel, MeteoViva EMS, although categorized as an Energy Management System, primarily functions as a sophisticated data analysis and visualization tool. This platform, which extracts and processes vast datasets from building operations, plays a pivotal role in identifying issues, predicting maintenance requirements, and fostering data-driven decision-making.

MeteoViva's innovative solutions transcend the boundaries of building types. They cater to a diverse spectrum of commercial and industrial buildings, including office complexes, production facilities, healthcare institutions, residential developments, wellness centers, airports, and sprawling university campuses. MeteoViva's technology is meticulously tailored to suit the unique requirements of each setting, reaffirming the company's position as a key player in advancing energy efficiency and sustainability [44]. One of MeteoViva's notable claims is that its solution can deliver energy savings of up to 40%. Beyond these impressive energy-efficiency gains, the quality of indoor environments is significantly enhanced. This assertion is reinforced by feedback from Generali, one of MeteoViva's clients, indicating a remarkable 90% reduction in employee complaints related to poor indoor climate. These substantial benefits are particularly pronounced in buildings with intricate HVAC systems [45].

The quality of MeteoViva's solutions has garnered the trust of renowned global entities, including Generali, Deutsche Bahn AG, and BMW Group. While these corporations may not utilize MeteoViva's solutions in all of their properties, the adoption of their technologies underscores the company's reputation for excellence [46]. Clients keen to leverage MeteoViva's solutions can do so through a straightforward subscription model. This entails a monthly fee, along with an initial installation cost. A noteworthy commitment made by MeteoViva is that the amortization period for their solutions is guaranteed to be less than five years. This transparent approach underscores the significant and rapid returns that clients can anticipate[44].

In a recent strategic innovation, MeteoViva introduced the "Smart Buildings as a Service" model. This offering integrates the capabilities of MeteoViva Climate, providing an innovative and comprehensive contracting solution. This strategic addition solidifies MeteoViva's commitment to leading the way in cutting-edge building management solutions and furthering their dedication to enhancing energy efficiency and sustainability [47].

Functionalities

The functionalities MeteoViva Climate offers focus on optimizing indoor climate control:

Advanced HVAC Control: MeteoViva Climate integrates building physics and various factors influencing indoor climate, such as occupancy, weather, and energy prices. It leverages this information to determine optimal heating or cooling energy and airflow for each building zone.

Energy Price Integration: What distinguishes MeteoViva Climate is its unique incorporation of energy prices into control calculations. This feature allows it to exploit low energy prices during periods of low demand, effectively reducing operational costs.

Real-Time Monitoring: Through the MeteoViva Cockpit app, users can monitor indoor climate and energy consumption in real time.

User Authorization: The app permits users, with the appropriate authorization, to adjust room temperatures based on real-time conditions.

Floor Plan Visualization: The app offers graphical representations of the building's floor plan, displaying temperatures in each zone and highlighting deviations from desired setpoints.

Anomaly Detection: MeteoViva proactively identifies malfunctioning or performance gaps and promptly sends alerts via SMS or email.

Compatibility: MeteoViva Climate seamlessly interfaces with existing building automation systems and can be deployed in both existing and new buildings. It operates independently of the HVAC system used in conjunction with the building automation system[48].

The functionalities of MeteoViva EMS focus on simplifying energy management. While labeled as an Energy Management System, MeteoViva EMS primarily serves as a tool for visualizing, analyzing, and managing data from building operations:

Multi-Building Support: It is designed to manage data from multiple buildings or entire portfolios, offering a holistic view of energy consumption.

Functionality Highlights: The system provides features such as consumption reports and forecasts, performance analysis of implemented measures, operational assessments, and email/SMS alerts. It also facilitates automated incidental cost reporting.

Data Sources: MeteoViva EMS aggregates data from various sources, including meters, sensors, the HVAC system, MeteoViva Climate (if used), energy bills, and manual inputs.

Data Visualization: The system effectively utilizes this data to detect anomalies and deviations and represents it in multiple formats, including a web application, exported PDFs, and Excel sheets[49], [50].

To summarize MeteoViva Climate functions as an intelligent HVAC control with its main functionalities being energy price integration, real-time monitoring, anomaly detection and an user-friendly app interface. MeteoViva EMS on the other hand focuses on energy management visualization, multi-building support, consumption analysis, automated reporting and data aggregation from various sources [51].

Marketing and Investment topics

MeteoViva's marketing strategy places a strong emphasis on cybersecurity and certifications, highlighting their commitment to data security and industry standards. Here are the key points related to their marketing and investment topics:

Cybersecurity Focus: MeteoViva highlights its commitment to cybersecurity in its marketing efforts. They position their solution as one of the few in the sector with an ISO 27001 certificate. This certification demonstrates their dedication to securing sensitive data and ensuring the privacy of their users [52].

Certifications and Sustainability: MeteoViva underscores the importance of certifications in their marketing. They claim that the use of MeteoViva Climate will earn a building at least a DGNB (German Sustainable Building Council) certificate in silver. This showcases their solution's contribution to sustainability and energy efficiency. Their MeteoViva EMS (Energy Management System) is presented as compliant with ISO 50001, emphasizing their adherence to international energy management standards[53].

Collaborations and Partnerships: In 2022, MeteoViva joined DENEFF, an initiative consisting of firms in the energy-efficient buildings sector. The goal of DENEFF is to influence policymakers and drive faster energy-efficient building transformations. MeteoViva's participation in this initiative reflects their active involvement in advocating for energy efficiency[54]. In late 2021, MeteoViva announced strategic collaborations and partnerships with industry leaders such as SAUTER, a building automation manufacturer, and Siemens Smart Infrastructure. These partnerships entail the integration of MeteoViva's solutions into

products offered by SAUTER and Siemens, expanding the distribution of MeteoViva's offerings in the market [55].

To conclude, MeteoViva's marketing strategy not only highlights their dedication to cybersecurity and adherence to industry standards but also emphasizes their role in promoting sustainability and energy-efficient building operations through certifications and strategic partnerships.

2.1.7. R8 Technologies

R8 Technologies, headquartered in Tallinn, Estonia, is at the forefront of advancing HVAC equipment operation. Specializing in the management of such systems, their flagship product, the R8 Digital Operator, harnesses the power of Artificial Intelligence (AI) to enhance HVAC control in commercial buildings, with a focus on hotels, offices, public facilities, and shopping malls. As of now, the company boasts a workforce of 47 dedicated professionals, according to their LinkedIn profile, who are instrumental in driving the vision of energy-efficient and sustainable building operation [56].

In addition to their core offering, R8 Technologies provides a comprehensive monitoring and diagnostics tool for HVAC equipment, which not only supports maintenance but also substantially reduces repair and operational costs. Importantly, this tool can function independently from the R8 Digital Operator. Customers seeking an advanced diagnostics and monitoring solution, while not necessarily focused on HVAC control, find this tool invaluable [57].

The company's pursuit of innovation extends to the concept of Virtual Power Plants. A complement to the R8 Digital Operator, the R8 Virtual Power Plant integrates a building's HVAC system with a virtual platform. When electricity providers seek to lower energy consumption to stabilize the grid and enhance power plant operations, the R8 Virtual Power Plant enables building owners to reduce their HVAC energy consumption within the stipulated timeframe and, in turn, earn financial incentives. Notably, this feature caters to high-energy-consuming buildings and is currently available only in Estonia[58]. R8 Technologies has expanded its footprint across 17 countries, catering to diverse markets. Their global presence encompasses Austria, Chile, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, and the United Kingdom [59].

R8 Technologies' commitment to sustainable energy management is underscored by the claim that they manage approximately 2.5% of Estonia's energy consumption. Their initiatives make them the largest energy consumption manager in Estonia, showcasing their significant contribution to the nation's sustainable future [60]. The core of R8 Technologies' solution is built upon three key performance indicators (KPIs): energy efficiency, ensuring desired indoor climate, and assessing technical condition through diagnostics and monitoring. The R8 Digital Operator leverages these KPIs to autonomously determine control commands, optimizing HVAC system operation [61].

Their solution promises remarkable results, with energy savings and a carbon emission reduction of at least 15%, potentially exceeding 30%, depending on specific use cases. Data from April 2023 indicates that their R8 Digital Operator achieved substantial monthly energy

savings. Shopping centers and office buildings saw a remarkable 24% reduction, while hotels and public facilities realized an impressive 17% reduction in energy consumption[62]. Apart from energy savings, R8 Technologies also claims to maintain indoor comfort rates exceeding 90%, validated by actual measured data. They anticipate that their diagnostic tool, R8 Diagnostics, will contribute to a 20% reduction in maintenance and renewal costs over the 20-year lifecycle of HVAC systems [57].

Functionalities

The R8 Digital Operator is a comprehensive HVAC control solution that optimizes indoor comfort and energy efficiency while minimizing costs. Here's a detailed overview of its functionalities:

1. HVAC Control and Optimization: The R8 Digital Operator controls and adjusts the settings of heating, ventilation, and air conditioning systems to optimize indoor comfort levels. This mostly concerns temperature control and airflow management.

2. Continuous Intelligent Adjustments: The system makes thousands of smart adjustments to the building's HVAC settings every month. These adjustments ensure that the indoor environment remains comfortable while reducing energy consumption.

3. Adaptation to Complex Buildings: The more complex the building, the better the R8 Digital Operator performs. Its adaptability and advanced algorithms are well-suited for buildings with intricate HVAC requirements.

4. Energy Efficiency Reports: Customers receive comprehensive monthly reports that detail the energy efficiency adjustments made by the R8 Digital Operator. These reports are easy to read and provide insights into energy savings and system performance.

5. Real-Time User Interface: The system offers a real-time user interface, allowing users to monitor HVAC settings and performance in real-time. This interface provides transparency and control over the system's operation[63].

6. Diagnostics, Monitoring, and Maintenance: In addition to control and optimization, R8 technologies offer advanced functionalities for diagnostics, monitoring, and maintenance:

- **Initial Diagnostics Report**: The system generates an initial diagnostic report that provides an overview of the current state of the HVAC equipment. It also suggests improvements to enhance energy savings.
- **Continuous System Analysis**: During operation, the system continuously analyzes HVAC system data. It employs a combination of rules-based, relational hierarchical models and statistical analysis of historical performance data to detect malfunctions or inefficiencies.
- **Error Reporting and Technical Support**: A standout feature is the capability to send errors and malfunction alerts directly to a team of technicians, typically the building's technical team. This ensures prompt and efficient resolution of HVAC system issues.
- **Maintenance Management**: The system can be used as a maintenance management tool, allowing for the assignment of maintenance tasks to specific individuals or teams. This streamlines maintenance and ensures the HVAC system operates under optimal conditions[57].

7. Electricity Peak Management: The R8 Digital Operator is designed to manage electricity consumption during peak periods when electricity prices are at their highest. It anticipates peak demand and adjusts HVAC settings accordingly.

8. Integration with R8 Virtual Power Plant: When connected to the R8 Virtual Power Plant, customers have the opportunity to earn financial revenue from electricity providers. This is achieved by reducing energy consumption during peak times, which helps stabilize the grid.

9. Consideration of Market Regulations: R8 technologies are aware that the financial profitability of the virtual power plant service depends on the specific market regulations of the country in question. They recognize that reducing energy consumption during peak times might result in higher energy consumption when the HVAC system reactivates due to the building's inertia. In some cases, the extra costs could outweigh the earnings from the virtual power plant[58].

To conclude, the R8 Digital Operator's multifaceted functionalities enhance energy efficiency, HVAC system performance, and financial sustainability, making it a standout solution in the field of AI-HVAC control.

Marketing and Investment topics

R8 Technologies is actively working on expanding its Virtual Power Plant Service to more countries. As of now, the service is exclusively available in Estonia, and the company has plans to broaden its geographical reach[58].

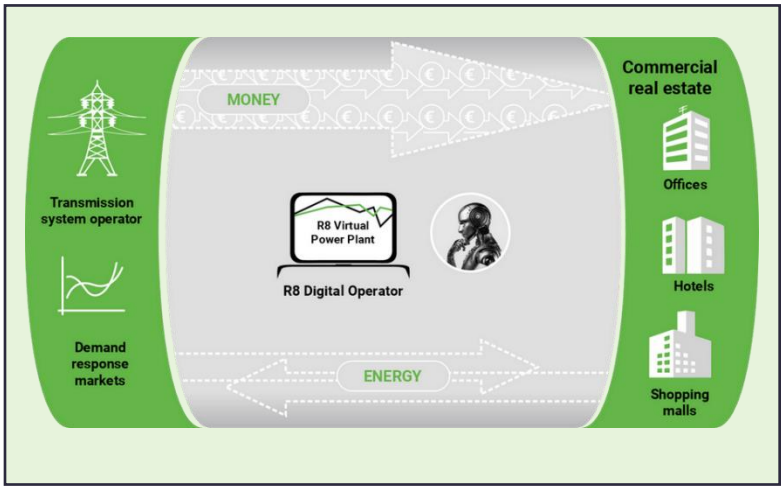


Figure 3: Graphical illustration of R8 Virtual Power Plant[58]

R8 Technologies has recently become a part of the RICS Tech Partner Programme. This strategic move is aimed at increasing awareness about their AI-HVAC control technology and expanding their presence in international markets [60].

In their marketing efforts, R8 Technologies places a strong emphasis on how their solutions can help businesses achieve their Environmental, Social, and Governance (ESG) goals. ESG is a critical aspect of corporate responsibility and sustainability, and R8's technology is positioned as a key enabler for these objectives.

In 2022, R8 Technologies demonstrated its commitment to education and skill development by offering a scholarship for a student studying at the School of Information Technology in Tallinn, Estonia. This initiative aligns with their mission to support and nurture IT talent.

R8 Technologies' focus on expanding its services, building partnerships, and promoting sustainability aligns with the growing global interest in energy efficiency and eco-friendly technologies. These activities not only benefit the company but also contribute to the broader goals of sustainable energy management and environmental conservation[64].

In summary, the R8 Digital Operator is a versatile and intelligent HVAC control system. It offers advanced features for optimizing energy efficiency, conducting diagnostics and maintenance, and even participating in energy flexibility programs through the Virtual Power Plant Service.

2.1.8. Shelly

Shelly, the flagship brand of the Shelly Group (formerly Allterco Robotics), emerges as a prominent European tech company specializing in the design, production, and distribution of high-quality Internet of Things (IoT) products. Notably, Shelly represents one of the fastest-growing IoT brands globally, providing innovative solutions for home and building automation. In a span of just a few years, the Shelly Group has made its mark in a staggering 100 markets across three continents. Presently, the company operates from three key offices: the European office, strategically positioned in the technologically burgeoning capital city of Sofia, Bulgaria; the United States office, which opened its doors in Las Vegas, Nevada, towards the end of 2019; and the German office, founded in Munich in 2021.

Shelly offers an extensive portfolio of smart home products spanning various domains such as lighting, heating and cooling, security, switching and triggering, energy metering, and an intuitive control application. Central to their offering are electrical relays, adept at controlling an array of devices encompassing lighting, appliances, kitchen equipment, doors, windows, fans, blinds, and even automatic pool covers. These relays are designed for installation in the electrical fuse box, providing control over the electrical circuits within your home. The seamless connectivity via Wi-Fi or Bluetooth facilitates convenient control through the dedicated Shelly App[65].

Moreover, Shelly extends its product range to include an array of sensors, including those for presence detection, window and door monitoring, temperature, and moisture. Smart valves, light bulbs, fire alarms, and sockets complete their comprehensive line-up. The versatility of Shelly's products is highlighted by numerous use cases. For instance, the integration of one of their relays with a moisture sensor empowers the automation of irrigation systems. This setup ensures that watering initiates automatically when the moisture level drops below a defined threshold, controllable via the app. Similarly, installing Shelly devices behind conventional light switches renders lighting smart and allows for dimming control[66].

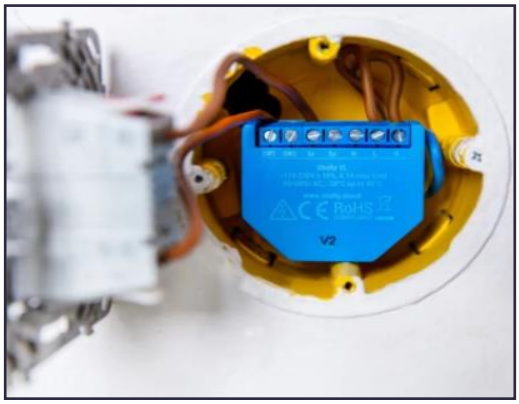


Figure 4: Shelly smart light switch

Shelly's contribution to the realm of home automation extends to energy metering devices, which can be easily installed behind standard power sockets. These devices diligently monitor energy consumption and efficiently transmit the data to the accompanying app via Wi-Fi. The company asserts that the adoption of their home automation solutions can lead to substantial savings of up to 30-40% on energy bills, ultimately contributing to a reduction in carbon emissions [67].

Functionalities

Shelly offers a wide range of home automation solutions with a focus on versatility and customization. Here's a detailed breakdown of the functionalities provided by Shelly to enable users to create their personalized smart home systems:

1. Modular Approach: Shelly follows a modular and adaptable approach, allowing users to mix and match products to create custom home automation systems. This flexibility ensures that individual needs and preferences are met effectively.

2. Lighting Control: Shelly provides lighting control options, including dimmed lighting and scheduling. Users can create specific lighting scenes to match various occasions or moods.

3. Energy Consumption Monitoring: Shelly's devices have the capability to measure energy consumption, with detailed data visualized in the app. The system can detect unusual changes in energy usage, signaling potential issues with connected devices. Maintenance notifications and warnings are sent via the Shelly App. Another functionality allows users to create scenes where multiple devices work in unison, allowing for tailored automation like a "movie night scene."

4. Leak Detection: Shelly's solutions include sensors for leak detection, such as water pipe leaks. Users receive alerts when a leak is detected, allowing for prompt action to prevent damage.

5. Heating System Control: Shelly can control heating systems using smart valves, providing individual room control and scheduling. It also manages domestic hot water supply, optimizing energy consumption by utilizing off-peak electricity rates.

6. Remote Control: The Shelly app offers remote control for a variety of connected devices, including heating, lighting, blinds, door locks, and more. It utilizes weather forecasts and data from installed sensors to send optimized control commands. The app also provides information about activities at the doorbell.

7. Two App Versions: Shelly offers two app versions - a basic edition and a premium version available through a subscription model. The premium version provides enhanced functionalities like more detailed energy consumption monitoring, monthly reports, and weather-based control[68].

8. Active Support Community: Shelly maintains an extensive support community, including an official Facebook group. Users can access tips, technical support, and ideas shared by fellow users and even the company's CEO.

9. Shelly Smart Control App and Cloud Access: While local network control is possible, using the cloud is recommended for the best user experience when utilizing the Shelly Smart Control App.

10. Control without the Shelly Smart Control App: Users can manage Shelly devices via their local embedded web servers, accessible through a web browser, or through an MQTT broker, providing versatile control options.

11. PC Access to Shelly Devices: Users can access Shelly devices from a PC by typing https://home.shelly.cloud into a web browser.

12. Sharing Access with Family Members: Shelly promotes family involvement by allowing up to 5 users per device. Users can use the "share" section under each device to set up user access sharing.

13. Estimated Power Consumption: Shelly devices are designed for energy efficiency, consuming no more than 1W when active, aligning with their mission to reduce energy consumption and costs.

14. Data Recording when Offline: No data is lost in the absence of a WiFi connection, as device energy usage data is continuously stored in internal memory and can be retrieved in .csv format.

15. Using Shelly Devices without Internet: Users can configure their own SNTP server to operate Shelly devices without an internet connection.

16. Outdoor Use Uncompatibility: Currently, Shelly devices are not suitable for outdoor use, lacking protection against outdoor elements like moisture and dust.

17. Battery Life Expectancy: Shelly provides battery life expectancy information specific to each product on their website, based on default settings.

18. Operation of Shelly's Battery-Powered Devices: Shelly's battery-powered devices remain in a low-power sleep mode, periodically activating to transmit data when changes in device indicators occur. Shelly's commitment to modularity, customization, energy efficiency, and user-friendly functionalities makes it a versatile choice for those looking to create a personalized smart home environment.

Marketing and Investment topics

Shelly positions itself as a provider of holistic smart home automation solutions, aiming to offer a versatile toolbox for creating individualized smart home systems. Their marketing and investment strategies are designed to cater to a diverse range of customers, including private residences, businesses, and luxury markets. Here's an overview of their approach:

1. Holistic Smart Home Solution: Shelly's primary marketing approach revolves around marketing their products not as individual items but as part of a comprehensive solution for smart home automation. They focus on providing a diverse range of products to meet various automation needs.

2. Targeted at Comfort and Luxury Markets: Shelly's website design and product offerings suggest a focus on selling comfort and luxury. This implies they are aiming at a wealthier customer base. Their product offerings for pools and spas align with this approach.

3. Diverse Applications: Shelly markets its products for use in not only private residential buildings but also in various commercial settings, including restaurants, hotels, and offices. The goal is to enhance the comfort and convenience of occupants in different environments [69].

4. Strategic Partnerships: In 2022, Shelly announced a strategic partnership with Blackwire Designs, a wholesaler specializing in audio, video, and security products. This partnership expanded Shelly's market reach and made their products more accessible to dealers and integrators for use in various projects. The press release indicates that Shelly intends to further extend its strategic partnership system. This suggests that building and nurturing strategic partnerships is one of their key investment areas. Collaborating with partners in the audio, video, and security sector could lead to new market opportunities and product integrations [70].

In summary, Shelly's marketing strategy focuses on providing holistic smart home automation solutions for both residential and commercial customers, with a particular emphasis on comfort and luxury markets. Their investment strategy involves establishing and expanding strategic partnerships, enabling broader market access and integration opportunities.

2.2. BEMS manufacturers assessment methodology

With the aim of analyzing the energy market and uncovering hidden market potentials, information regarding various manufacturers is utilized to compare these products and manufacturers against one another. This approach enables the identification of saturated market areas and regions with low market saturation. To achieve this, an assessment framework was developed as a basis for comparison. Within this framework, each product is first categorized into a specific product category. Subsequently, an evaluation of each product within its category is conducted, based on six criteria: service impacts, functionalities, market penetration, investment aspects, business model, and value proposition. The categorization into product categories and the evaluation of the six criteria will be elucidated in the subsequent paragraphs.

2.2.1. Product category

To facilitate a more detailed analysis, each product is categorized into a specific product category. Based on initial market research and the identification of products and services commonly produced by most manufacturers, six product categories were established: smart thermostats with Wi-Fi gateway and control app, smart valves with Wi-Fi gateway and control app, HVAC control, data and energy acquisition and management software, Smart Home Ecosystem, and Home Energy Management System. These categories are delineated on the left-hand side of the assessment matrix.

2.2.2. Service Impacts

The service impacts of each product are evaluated in seven different impact categories which are derived from the Smart Readiness Indicator (SRI): energy efficiency, maintenance and fault prediction, comfort, convenience, health and well-being, information to occupants, energy flexibility and storage. Depending on the functionality delivered, each product is assessed with a score between zero and four, with zero being the lowest score and four being the highest score.

A score of zero is given when a product doesn't address an impact category at all. A score of one means that a product has an effect on the impact category, but the impact is relatively small and the user is unable to actively influence the operation of the product and thus the influence on the impact category. A product having a medium effect on the impact category and offering the ability for the user to actively influence the operation of the product corresponds with a score of two. When a product has a high effect on the impact category and not only enables the user to influence the operation but also informs the users thoroughly on the effect of their actions, a score of three is given. The highest score in achieved when a product performs in a constant self-optimising way (e.g., self-learning algorithms) and can operate autonomously. Furthermore, products with a score of four not only inform the user about the effects of their actions, but also give personalized recommendations concerning actions to take. A detailed breakdown of the scores for each impact category will be given later in this section.

For better visualization, each score between zero and four corresponds with a colour progressing from a red colour for the lowest score to a dark green for the highest score as shown in the figure below. This way, saturated areas of the market can be easily detected by looking for areas predominantly dominated by green colours whereas market potentials lie in the areas predominantly represented by red colours.

Table 1: Service impact levels combined with color coding for assessment

None	0
reporting on current electricity consumption on building level	1
real-time feedback or benchmarking on building level	2
real-time feedback or benchmarking on appliance level	3
real-time feedback or benchmarking on appliance level with automated personalized recommendations	4

The assessment is carried out in a table in Microsoft Office Excel. Here is a breakdown of the seven categories:

1. Energy efficiency: The field of energy efficiency gives insight into the amount of energy savings a solution achieves. For the evaluation of this category the claimed saving percentages of each manufacturer is considered as well as the amount of data used to determine smart control commands and the complexity of the algorithm, e.g. the automatic detection of open

windows or the inclusion of the weather forecast into the calculation presents a more advanced algorithm and leads to a higher score.

2. Maintenance and fault prediction: For the evaluation of the maintenance and fault prediction ability, reduction percentages of downtimes and maintenance costs are considered as well as the degree of insight into the malfunctioning. A system giving users detailed information on the malfunctioning together with personalized recommendations on how to proceed with it leads to a higher score than the mere reporting of anomalies.

3. Comfort: This category aims at quantifying how the well-being and physical comfort of occupants is affected by the solution. Heating and cooling adapting dynamically to the occupants needs and the monitoring and improvement of air quality and thermal comfort are the main evaluation criteria for this category.

4. Convenience: Where the category of comfort aims at evaluating the personal comfort of the occupants, the category of convenience evaluates the usage and appliance of the solution. Products must be easy to install and set up, intuitive to use and integratable into existing systems in order to be perceived as convenient. In broad terms, when a system requires less user intervention due to higher automation, it tends to receive a higher convenience rating.

5. Health, well-being and accessibility: The field of health, well-being and accessibility is assessed by the amount of monitoring and analysis each solution provides concerning health related factors. These factors predominantly are the noise level, air quality and humidity level. Systems alerting occupants when certain thresholds are passed, giving personalised recommendations on improving indoor climate conditions and automatically taking actions to maintain a healthy environment contribute to an assessment with a higher score in this category.

6. Information to occupants: In order to achieve a high score here, products must provide detailed insights into the operation of a system. The more accurate the information on runtime, energy consumption, historical data and real time data is, the higher the score given to a product. An intuitive visualisation of the data and the ability to influence the performance of a product also are considered for the evaluation of this category.

7. Energy flexibility and storage: The score of this category is based on the ability of load shifting, the increasement of electrical self-consumption rates, the contribution to stabilizing the grid, enabling new energy storages and the use of dynamic energy tariffs.

2.2.3. Functionalities

The main functionalities and working principle of each product are documented with the five main functionalities being: HVAC control, Data visualization and control app, Virtual Power Plant, Home Energy Management System and AI modelling. These main functionalities have been marked on the right-hand side of the service impact assessment in the matrix.

2.2.4. Market penetration

To evaluate the market penetration of each manufacturer, a field was added to the table that lists all countries each manufacturer is active in. Furthermore, the usage of each product is categorised by building type within the sheet. The categorisation into residential, commercial, and industrial use gives valuable insight into the specific market targeted by each manufacturer.

2.2.5. Investment topics

To not only evaluate the current state of each manufacturer but to also allow for future predictions of the market evolvement, information concerning the research, marketing and investment topic of each competitor was gathered and structured in the Excel sheet.

2.2.6. Business model and value proposition

In addition, information regarding the business model of each competitor was gathered and value propositions documented.

For the analysis of the business model, it is analysed which customers are targeted primarily by the product. Some competitors focus on private individuals, some even more specifically on luxury products for rather wealthy individuals, whereas others focus on customers from the industrial, public or real estate sector. Furthermore, business models can be distinguished by the way they generate profit: some competitors rely on conventional sales where the costumer pays a fixed price and then owns the product. Others try to generate continuous financial flows by offering their products as a subscription or contracting model or by providing software as a service.

The field for value proposition in the assessment matrix documents aspects of the marketing that make a product stand out from its competitors and couldn't be documented in the previous categories. Examples are the emphasis of high integrability into a larger ecosystem from the manufacturer or the aggregation of all functionalities in a single device.

2.3. BEMS manufacturers evaluation

2.3.1. BEMS Assessment matrix

The conducted work is portrayed in the assessment matrix below. This matrix provides a comprehensive evaluation of Building Energy Management Systems (BEMS) manufacturers. It includes detailed information on market penetration, investment topics, business models, and value propositions. By systematically categorizing and assessing products and manufacturers, the matrix identifies both saturated and low saturation areas in the market. This thorough approach allows for uncovering hidden market potentials and provides a nuanced understanding of the energy market dynamics.

Table 2: Assessment matrix of manufacturers active in BEMS

Product	manufacturer	Service impacts						
		energy efficiency	maintenance and fault prediction	comfort	convenience	Health, well-being and accessibility	information to occupants	energy flexibility and storage
Smart thermostat with wifi	TADO	4	3	3	3	3	2	1
	Netatmo	3	3	3	2	3	3	0

gateway and control app	Google Nest learning thermostat	3	2	2	4	0	1	1
	Bosch Easy Control	3	4	2	4	0	2	0
	Homix	3	0	2	4	0	1	0
	KONO smart thermostat	2	0	4	1	2	2	0
	Bosch Room thermostat II 230V	1	0	3	3	3	1	0
Smart valves with wifi gateway and control app	TADO	4	3	3	3	3	2	1
	Netatmo	3	1	3	3	3	3	0
	Bosch Smart Radiator Thermostat)	3	1	2	2	0	2	0
HVAC control	BrainBox AI	3	2	2	4	3	4	0
	BEEBRYTE	4	2	2	4	1	3	0
	DABBEL	4	1	2	4	2	3	0
	R8 TECH	3	3	3	4	2	3	2
	MeteoViva	4	2	2	3	2	3	1
data & energy acquisition/ management software	METRON	2	1	0	3	0	4	2
Smart Home Ecosystem	Shelly	4	3	4	2	0	3	1
Home Energy Management System	Bosch Energiemanager	4	1	2	3	2	4	3

The assessment matrix presented in the table provides a detailed evaluation of various manufacturers, offering a comprehensive insight into the current state and potential of the energy market. This matrix is structured to systematically compare products and manufacturers across multiple dimensions, enabling the identification of both saturated market areas and regions with untapped potential.

The evaluation criteria for the next step encompass six key areas: service impacts, functionalities, market penetration, investment aspects, business model, and value proposition. The service impacts are assessed across seven impact categories, including energy efficiency, maintenance and fault prediction, comfort, convenience, health and well-being, information to occupants, and energy flexibility and storage. Each product is rated on a scale from zero to four in these categories, with color-coded scores to visually distinguish between high and low performing areas.

Functionalities are documented to highlight the main working principles of each product, with specific focus areas such as HVAC control, data visualization and control apps, virtual power plants, home energy management systems, and AI modelling. Market penetration is evaluated by listing the countries each manufacturer operates in and categorizing product usage by building type—residential, commercial, or industrial.

Investment topics provide insights into each manufacturer's research, marketing, and investment strategies, allowing for predictions of future market developments. The business model analysis focuses on customer targeting and profit generation methods, while the value proposition section highlights unique marketing aspects that differentiate products from their competitors.

Table 3: Scope and investment models of manufacturers active in BEMS

Product		Market penetration		Investment topics			business model
	Manufac-turers	Building usage	Countries/Continents	Research	Marketing	Latest Investments	
Smart thermostat with wifi gateway and control app	TADO	residential	27 countries in Europe, European market leader for indoor climate management	dynamic energy tariffs, energy management	combined products for private households, cooperation with housing associations	acquisition of aWATTar GmbH (company for load transfer and dynamic energy products)	
	Netatmo		complete European Union + UK, Norway, Switzerland, Liechtenstein, Iceland + Canada + USA + Mexico	IoT, new industrial partners	co-creations with partners like aldes, velux, vaillant		
	Google Nest learning thermostat		Belgium, Canada, France, Ireland, Italy, Netherlands, Spain, United Kingdom, United States	compatibility of google products with one another, user convenience, AI	Smart home byconnecting several google products and combining, updated google home		
	Bosch Easy Control	residential	Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Kosovo, Latvia, Lithuania, Macedonia, Malta, Moldova, Montenegro, Netherlands, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Turkey, Ukraine, United Kingdom **(interestingly not Sweden, Norway, Finland)**	compatibility with underfloor heating systems	marketing to businesses: they market their Bosch HomeCom Pro system to heating installers to monitor their costumers heating systems; marketing of whole heating systems and relations to local heating installer		
	Homix	residential	Spain, Italy, Romania	partnerships to gain access to new markets	high focus on user friendliness and convenience, claim HomiX to be more cost-efficient and		sales to private individuals (concerning HomiX); EnelX

					budget-friendly that the solutions from their competitors		mainly offers B2C, B2B and B2G solutions
	KONO	residential	150 countries	strategic distribution partnerships	modern design and personalization (exchangeable front plate to adapt to personal style preferences)	acquisition of M&M Carnot to enhance sustainable Industrial Refrigeration portfolio in June 2023	sales to private individuals via authorized distributers
	Bosch Room thermostat II 230V	residential	14 countries in Europe: Austria, Belgium, Denmark, France, Finland, Germany, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland	expanding partner network (making more third-party products compatible with their smart home system)	compatibility; simpleness; reliability; data security		sales to private individuals; aiming at selling whole smart home systems
Smart valves with wifi gateway and control app	TADO		27 countries in Europe, European market leader for indoor climate management	dynamic energy tariffs, energy management	combined products for private households, cooperation with housing associations	acquisition of aWATTar GmbH (company for load transfer and dynamic energy products)	
	Netatmo		complete European Union + UK, Norway, Switzerland, Liechtenstein, Iceland + Canada + USA + Mexico	IoT, new industrial partners	co-creations with partners like Aldes, Velux, Vaillant		
	Bosch smart radiator thermostat	residential	Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Italy, Kosovo, Latvia, Lithuania, Macedonia, Malta, Moldova, Montenegro, Netherlands, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Turkey, Ukraine, United Kingdom **(interestingly not Sweden, Norway, Finland)**	compatibility with underfloor heating systems	marketing to businesses: they market their Bosch HomeCom Pro system to heating installers to monitor their costumers heating systems; marketing of whole heating systems and relations to local heating installer		
HVAC control	BrainBox AI	commercial (e.g. retail stores, office buildings, shopping malls, airports, hotels)	globally: 18 countries including Australia, Belgium, Brazil, Canada, Greece, Ireland, Italy, Japan, Jordan, New Zealand, Qatar, Saudi Arabia, Thailand, United Kingdom, United States of America, and Uruguay. Since then they expanded to even more countries which remain unnamed	building partnerships, joint product development (e.g. with ABB), recently 20 million dollars for further development	complete solution for reducing greenhouse gas emissions, they have a sector dedicated to selling and managing greenhouse gas offset projects so that a building can claim climate neutrality	Acquisition of ABB's multi-site retail (MSR) energy management system integrator business	
	BEEBRYTE	commercial and industrial	Europe and Asia (countries not know), offices in France and Singapore	raising funds and investors for further development	marketing especially to refrigeration and large scale cooling sector		subscription, software as a service
	DABBEL	commercial (especially real estate and offices)	12 countries: USA, UK, Netherlands, Germany, Switzerland, Austria, Slovakia, Poland, United Arab Emirates, China, Australia, New Zeeland	building partnerships, scalability, reducing installation time	marketing for commercial usage, focus on real estate sector, emphasis on not needing any additional hardware		subscription, software as a service
	R8 TECH	commercial and public buildings (mainly hotels, offices, public buildings, shopping malls)	17 countries: Austria, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland, United Kingdom; Virtual Power Plant currently only in Estonia	expanding to new overseas market, virtual power plants	reaching ESG goals		subscription
	MeteoViva	commercial and public buildings)	Europe and USA: Germany, Netherlands, Belgium, Luxembourg, France, Switzerland, United Kingdom, USA	taking political influence as part of DENEFF; collaborations	cyber security (according to ISO 27001), certificates of their products (DGNB certificates, ISO 50001)		subscription, sustainable buildings as a

				and strategic partnerships			service (contracting)
data & energy acquisition/ management software	METRON	commercial *(production, tertiary sector, public sector)*	France, Italy, Belgium, Switzerland, Poland, Romania, Turkey, Germany, Spain, UK, Ireland, Netherlands, Russia, Saudi Arabia, Colombia, Mexico, Argentina, Chile, Brazil, Canada, USA, Singapore, South Korea, Japan, Vietnam, Malaysia, Indonesia, Thailand, India, China, Australia New Zealand, Morocco and Ghana	research network of PhDs and laboratories, decentralized technologies, algorithms, part of CleanTech ecosystem	marketing exclusively to businesses, they market METRON to be applicable to almost every sector and need, they market knowledge and expertise by providing e-books to business leaders	Acquisition of Dapesco in 2021, a consultancy that offers an energy management platform	
Smart Home Ecosystem	Shelly	residential, offices, restaurants, hotels	more than 100 markets on 3 continents	expansion of strategic partnership network	comfort, rather wealthy costumers		sales to rather wealthy private individuals, restaurants, hotels, offices, premium version of the app comes as subscription model
Home Energy Management System	Bosch Energiemanager	residential		new features for the app; IoT; digitalization; Joint Venture; 350 million dollars for supply chain of semi-conductors	compatibility; expertise; experience		sales to private individuals (concerning Energiemanager)

Overall, this matrix serves as a robust tool for understanding the landscape of BEMS manufacturers, offering a detailed and nuanced analysis that highlights market trends, identifies opportunities, and provides strategic insights for stakeholders in the energy market.

2.3.2. Detailed evaluation of manufacturers

In this section, we provide an in-depth analysis of various manufacturers, focusing on their performance across multiple assessment criteria. Each manufacturer is evaluated based on their product offerings in the domains of energy flexibility, maintenance and fault prediction, comfort and convenience, health and well-being, information to occupants, and energy storage.

Bosch

Energy flexibility was assessed with a relatively low score. Unlike other manufacturers, the Room Thermostat II 230V neither takes the weather into account nor does it make use of geofencing or seems to be able to modulate the heating generator itself. All of this leads to the low score.

Concerning maintenance and fault prediction, the thermostat does not provide any functionalities which leads to the minimum score. In the two areas of comfort and convenience, they achieved a relatively high score due to scheduling and especially the built in air quality sensor, the ability of voice controlling and the high compatibility with other Bosch smart home and third-party products.

In the area of health and well-being, the product also achieved a relatively high score which mainly is due to the built in air quality sensor and the ability to use this data about the air quality to automatically trigger air humidifiers or send alerts. Furthermore, the thermostat changes the colour of its led lights as soon as certain humidity thresholds are passed. The

only thing hindering them from achieving the highest score is the lack of personal recommendations. The amount of information to the occupants is relatively low. Especially the lack of access to historical data leads to the low score in this field. Since the thermostat does not provide any functionalities for flexibility or energy storage, the thermostat is assessed with the lowest score here.

Beebryte

In the field of energy efficiency BeeBryte is assessed with the maximum score since they claim up to 40% savings on energy costs. They also achieved quite a high score for maintenance and fault prediction since they monitor the system 24/7 and can predict technical failures when higher energy consumption of a device is detected. Since the solution is especially suitable for vulnerable and sensitive applications (e.g., cooling chains) it is rated with a higher score than its competitors since the value proposition for more critical processes is higher.

On the contrary the sore for comfort is in the middle since it only improves the thermal comfort of the occupants which is the standard expectation for a product of this category.

As most AI HVAC controls, the solution is rated with the maximum score in the field of convenience since it (almost) works completely on its own. Compared to the need for manually controlling the HVAC system, the AI based control is a huge upgrade and takes over a lot of work that had to be done manually before. Furthermore, the operation of the site doesn't need to be interrupted for the installation and BeeBryte takes over all the costs and responsibility for the installation making the whole process very convenient for the customer. With the help of the app users also get easy access to energy performance data.

In the field of health and well-being, BeeBryte was assessed with a relatively low score. It for sure increases the well-being of the occupants (e.g. in shopping centres) by keeping temperatures at a constant level but a big part of their focus lies on cooling for industrial processes where well-being is relatively unimportant.

The information to the occupants (or at least to the operators having access to the dashboard) is quite high and the dashboard even allows for customization of the data visualisation.

Concerning flexibility and energy storage, BeeBryte doesn't hold any improvement compared to a system without BeeBryte, which is the reason for the lowest score (red).

Dabbel

The category for energy savings can be assessed with the maximum score since the technology is proved to achieve considerable amounts of energy saving. Energy saving of to 40% is very close to the theoretically maximum amount of energy savings possible.

In the area of maintenance and fault prediction the score is relatively low since other competitors offer many more functionalities such as sending detailed error alerts or even giving recommendations on how to proceed with the error. The only thing DABBEL does is to report on anomalies without offering more detailed information.

The effect on comfort is also relatively low since it only increases the thermal comfort by keeping room temperatures at a constant level. To be fair, additional hardware would be necessary to improve the comfort more significantly.

In the area of convenience DABBEL achieves the highest score since it almost works completely on its own by learning behaviours autonomously. Compared to the need for manually controlling the HVAC system, the AI based control is a huge upgrade and takes over a lot of work that had to be done manually before. Furthermore, DABBEL doesn't need any additional hardware, making the installation process very convenient. With the help of the app users also get easy access to real time energy performance data.

Concerning health and wellbeing DABBEL increases the air quality and keeps the temperature at a constant level but since this is the only thing it does in this area, the score is in the middle.

The amount of information to the occupants is quite high (given that you have access to the app) which leads to the second highest score. Other competitors although offer functionalities such as a comparison of the own building to other buildings which is why DABBEL wasn't assessed with the maximum score here.

Since DABBEL doesn't contribute to flexibility and energy storage at all, the score here is zero (red).

Homix

The area of energy efficiency was assessed with the second highest score. This is due to the fact of a highly developed scheduling algorithm which learns the habits of the occupants and automatically adapts the schedule using geofencing. The missing functionalities for the detection of open windows and recommendations to the user on how to further improve the energy efficiency are the reason the product is not assessed with the highest score.

The impact area of comfort is addressed by the functionality of scheduling which improves the thermal comfort noticeably. Since there is barely any interaction and recommendations to the user concerning the indoor climate comfort, the technology is assessed with the middle score of 2.

HomiX reached the highest score in the impact area of convenience. The high compatibility with other products and the ability to function as a Smart Home controller as well as the user-friendly control-app make HomiX eligible for the highest score in this area.

Information to the occupants is limited to the minimum which qualifies HomiX for the score of 1 only. Especially the lack of monthly reports or real time monitoring are the reason for the low score.

Since the impact areas of maintenance and fault prediction, health and well-being as well as energy flexibility and storage aren't addressed at all, they are assessed with a score of 0.

Johnson Controls (Lux Products)

In the impact area of energy efficiency Johnson Controls reached the middle score of 2. It offers the basic functionalities of a smart thermostat mainly being scheduling and geofencing but the interaction with the user is quite low and it misses some common functionalities which enhance energy efficiency, e.g. AI based algorithms to learn the habits of users or the thermal inertia of the building. That's why the smart thermostat wasn't assessed with a higher score here.

In the area of comfort, it is the only smart thermostat that was able to achieve the highest score. This is due to the in-built air quality sensor and the ability to run the thermostat in air

quality mode, which specifically determines control commands focusing on higher indoor air quality. Furthermore, the thermostat allows for customized design which also contributes to the high score.

On the contrary, the thermostat only reached a score of 1 in the impact area of convenience which is the lowest score of all thermostats. This field only is addressed by the user-friendly control app which is very little compared to most other manufacturers. In fact, Johnson Controls offers less functionalities for this impact area than any other competitor which is the reason for the low score.

Health and well-being is addressed with the air quality mode of the thermostat. Still a lot more could be done here, especially interaction and recommendations to the user. This leads to the middle score of two.

Same applies to the information to occupants. The information is kept very brief, e.g. there is no information on real-time performance or historic data. Still, the utility cost is estimated which is rather distinctive compared to other manufacturers. All of this leads to the medium score of 2.

Maintenance and fault prediction as well as energy flexibility and storage aren't addressed at all which is why they were assessed with the lowest score.

MeteoViva

With energy savings of up t0 40%, MeteoViva earns the maximum score in the field of energy efficiency. Maintenance and fault prediction was assessed with a medium score since their MeteoViva EMS service comprises of a detailed monitoring function, sends alerts in case of performance gaps and offers the ability to activate actuators when specific errors occur. More information on the errors and recommendations on how to fix the errors would be necessary to gain a higher score here.

Increasing the indoor air quality earned MeteoViva a medium score in the fields of comfort and health, well-being & accessibility. The lack of recommendations to the building occupants is preventing them from earning a higher score.

Concerning convenience MeteoViva didn't achieve the maximum score like most competitors. This is due to the installation process seeming more complex and the fact that other solutions seem to have a more advanced self-leaning algorithm.

Information to occupants is assessed with the highest score since the MeteoViva Cockpit App enables information to get to every user of the building. Furthermore, they have a complete service (MeteoViva EMS) in their portfolio dedicated to analysing and visualizing large amounts of data.

For energy flexibility and storage, MeteoViva was assessed with a relatively low score. Flexible energy tariffs are only used and seen from the perspective of optimizing costs for the operator and not from the perspective of stabilizing and interacting with the grid or offering opportunities for energy storage at all. A more wholesome approach here would be necessary for a higher score.

R8 Technologies

In the area of energy efficiency R8 technologies is rated with the second highest score since their solution can achieve more than 30% savings on energy consumption and carbon emissions, which is quite a remarkable number. Since other competitors reach percentages of up to 40%, R8 tech isn't rated with the maximum score.

Concerning maintenance, R8 technologies offers more advanced functionalities than other competitors with AI-HVAC control products, especially the ability to assign maintenance tasks directly to a team of technicians. The only aspect preventing them from reaching the highest score here is, that the software does not give specific advice on how to fix the problem, but it is up to the technician to figure this out.

In the field of comfort, they reach a slightly higher score than most of their competitors since they put a higher focus on the comfort of the building occupants than their competitors. At least that's what it seems like from their marketing.

Like most other similar products, R8 Digital Operator is assessed with the maximum score for convenience. Compared to the need for manually controlling the HVAC system, the AI based control is a huge upgrade and takes over a lot of work that had to be done manually before. The short installation process, the easier detection of malfunctioning and the real time interface all contribute to the high score. The score for health and well-being is in the middle of the scale since it improves the inner air quality of the building. The lack of specific monitoring of the air quality and advice on how to improve the health of the occupants hinders the technology from achieving an even higher score.

Real time user interfaces and monthly reports qualifies them for the second highest score in the field of information to occupants. Important for the second highest score is the access to real time data and information. It must be noticed that most of this information only is accessible for the building operator not for the occupants themselves, e.g. people working in an office building of visitors of a shopping mall usually don't have access to this information so the score here is more based on the information provided from the system and not so much on the distribution and availability of the data for a wide amount of people.

In the area of flexibility and energy storage, R8 Digital Operator is one of few AI-HVAC controls that actually offers functionalities in this area. Since the solution only supports flexibility by incentivising the shifting of energy consumption when useful for the energy grid but not offering any functionalities for energy storage, the solution is only assessed with a medium score.

Shelly

Shelly claims energy savings of 30-40% with their solution. The high percentage together with the ability to control any power consuming device leads to the maximum score in the impact area of energy efficiency.

Concerning maintenance and fault prediction, Shelly is able to monitor the energy consumption of devices, to conclude malfunctioning from that and to inform occupants about it. Furthermore, they offer sensors especially dedicated to detecting malfunctioning which is why Shelly was assessed with the second highest score in this impact area. More detailed information concerning the malfunctioning and personalized recommendations on how to proceed with the error would be necessary to reach an even higher score.

Shelly focuses on selling comfort-related products to rather wealthy individuals all with the goal of increasing the comfort of their customers. Users can build own systems according to their wishes which makes it no surprise that Shelly reached the maximum score here.

On the contrary, the complex systems and hard to install elements lower the score for convenience to a score of only 2. Health and well-being is not addressed by Shelly's solutions which is the reason for a score of 0 in this area. The amount of information to the occupants is quite high with information being available on real-time performance and historic data on a monthly basis. Furthermore, Shelly alerts the user in case of malfunctioning. All of this together leads to the second highest score in this impact area. The field of energy flexibility and storage is hardly targeted by Shelly. Only the ability to save energy costs by programming Shelly devices in a way that night tariffs are exploited contribute to the score here. Therefore, Shelly is assessed with a score of 1 for energy flexibility and storage.

2.4. BEMS SWOT analysis

Based on the assessment matrix a SWOT-analysis is carried out. The SWOT-analysis aims at identifying strengths, weaknesses, opportunities, and threats of a market and concludes adequate strategies from them.

The area of strengths focuses on identifying market segments that are saturated with a high number of products with high quality. These are usually market segments where products comprise a similar functionality and quality and competitors hardly stand out from one another. Competition and customer expectation are high and the market is able to fulfil the needs of consumers. On the contrary, weaknesses of a market lie in segments where the quality of products differs a lot. Needs of customers aren't met adequately and offer a lot of space for development and improvement.

Opportunities of a market usually lie in the weaker segments since they hold the option to develop outstanding characteristics. Products strategically serving weaker market segments are likely to be innovative and in front of the general market development. Opportunities not only lie in the development of innovative products but also in changing user patterns or business models. Market threats describe internal or external challenges that might hinder the success of a product. This can be due to governmental or political movements but also because of new competitors and unforeseen events. Obstacles that complicate the installation or operation of a product for consumers also present threats.

After having collected data on the strengths, weaknesses, opportunities and threats of the market as well as the own business, strategies are conducted from the intersection of them. The intersection of strengths and opportunities (S-O strategies) aims at using strengths to exploit opportunities. The own strengths are used to serve market potentials and increase the possibility of success. On the other hand, the combination of strengths and threats (S-T strategies) tries to use the own strengths to eliminate threats. Strengths are used to face threats and prevent them from becoming a danger.

The intersection of weaknesses and opportunities (W-O strategies) develops strategies to change weaknesses into strengths. Opportunities can be used to learn and work on the own weaknesses in order to develop them into strengths. Finally, the combination of weaknesses and threats (W-T strategies) identifies strategies to avoid threats. Measures are taken to

navigate around threats in order to not become a target of them. The results of the SWOT analysis are shown in the SWOT-matrix below.

Table 4: SWOT analysis of key European BEMS manufacturers

	Opportunities	Threats
	• rising demand for comfort increasing products • information to occupants: interfaces, graphical dashboards, real-time monitoring, detailed reports • IoT integration (gateways necessary)	• increased customer expectations • highly competitive market • quickly changing regulations • requirements differing by climate zone and country • installation challenges
Strengths	S-O strategies	S-T strategies
• highly developed technologies concerning energy efficiency • user-friendly and convenient products • control apps with advanced functionalities	➢ new business models, e.g. subscription/ contracting ➢ IoT gateways and ports to anticipate future market developments	➢ customer interaction ➢ strategic partnerships and cooperation ➢ installation support
Weaknesses	W-O strategies	W-T strategies
• energy flexibility and storage barely addressed • lacking integration of health functionalities into one product • maintenance and fault prediction algorithms • difficult installation of some products	➢ personalized health recommendations ➢ AI based predictive maintenance algorithms ➢ linking data to cloud ➢ energy management systems for flexibility and storage	➢ expansion to new countries ➢ incentives to build trust

2.4.1. Strengths

With the help of the assessment matrix, two service impacts can be identified where the market already reached an advanced state. In these areas the market offers strong solutions for consumers and competition is very high.

As shown in the assessment matrix, the BEMS market offers very advanced products concerning energy efficiency. Nearly all competitors reached a high or very high score here. Percentages of energy savings differ between the manufacturers but usually lie between 30-40%. The market here seems to be saturated both for residential and for commercial usage.

The second strength of the market lies in the area of convenience. In this impact category competitors reached equally high scores as in the impact category for energy efficiency.

In both of these impact categories products are highly developed and the room for innovation is small. Manufacturers that want to enter the market must at least align with the high standards in these impact categories to be able to compete. The probability of a new product being introduced to the market that outstand all other competitors in these impact categories is low.

Most manufacturers also offer control apps for smartphones which come with a product. This makes the control of systems convenient for occupants and presents a strength of the current market.

This leads to four trends which can be observed on the European market: firstly, competitors try to expand their reach to new countries. If a market in one country is saturated, one option is to expand to the markets of another country. Especially markets in Eastern Europe will be in the focus in the future, which can be drawn from the fact, that these countries are the countries where products have been launched lately. These are also the countries with a cold climate in winter and thus hold more potential for heating products than countries with warmer climate. Secondly, manufacturers seek to build partner networks with the goal of gaining access to existing customer relations but also to profit from the know-how of one another. Since products are becoming more and more complex, the need for expertise rises which is why many manufacturers form strategic partnerships to use their expertise in shared developments. The third trend is that large companies acquire smaller companies which hold expertise and customer relations in specific market segments. The fact that larger companies are able to establish their products persistently is a sign that the market is transitioning into a more advanced state. Finally, manufacturers tend to adapt to new business models in order to attract new customers. The trend here goes to subscription and contracting models especially in the commercial and industrial sector, but it can be expected to reach the private sector soon as well.

2.4.2. Weaknesses

On the contrary the market has clear weak spots in the impact categories of energy flexibility and storage as well as health, well-being and accessibility.

Only a few products were able to reach a score higher than zero in the area of energy flexibility and storage. A common approach to address the area of energy flexibility and storage is cooperation with energy suppliers to offer products that make use of dynamic energy tariffs. It must be mentioned that most of the products cannot provide energy flexibility or storage on their own. Only in combination with an energy management system can they unfold their potential here. Still, there lies a lot of potential for further development here. Products must provide the necessary ports and gateways to communicate with energy management systems and the grid. Surely flexibility and storage solutions can be found that profit the consumer financially and stabilize the grid by shifting loads.

The area of health, well-being and accessibility is hardly targeted by some manufacturers whereas others already offer advanced systems here. One difference between the manufacturers lies in the level of integration into one single product: some manufacturers offer products that have sensors included which can be used to give health advise to the occupants, whereas other manufacturers require an external sensor for this service. Here lies an opportunity to integrate health-functionalities into the product to stand out from competitors.

Another weakness of the market lies in the area of maintenance and fault prediction. Some products don't offer any functionalities here at all. With the help of smart algorithms, products can be developed that fill this gap. One approach could be the sharing of data with a cloud-based platform which then detects malfunctioning and might even arrange contact to local repairmen where needed.

The hard installation of some products presents a hurdle to customers. An extensive customer support is needed for some products to familiarize occupants with the new systems. Other products can be installed easily by the consumers themselves.

2.4.3. Opportunities

Opportunities and market potentials lie in the weak spots of the market mainly being energy flexibility and storage, health and well-being as well as maintenance and fault prediction.

But opportunities also lie in areas, where competitors differ from one another. The amount of information to the occupants varies severely between the manufacturers. Easy to use interfaces, graphical dashboards, real-time monitoring and detailed reports are possibilities to place the user at the centre. Algorithms that are able to suggest further actions to the occupants in order to improve energy efficiency, health and comfort hold the potential to foster interaction with the customer and build excitement for a product. Examples would be automatic suggestions on improving heating schedules or ventilation recommendations for higher indoor air quality.

Another option to put occupants at the centre is to focus on the impact category of comfort. Hardly any competitor reached the highest score here. Self-learning algorithms that notably improve indoor comfort are a way to address the needs of customers and gain advantages over others. It is important that occupants are able to adjust indoor climate and comfort according to their wishes and needs and are able to control and understand the operation of a system at any time.

With the rise of IoT the development of products capable of communicating and taking advantage of IoT-systems also gains importance. Providing adequate gateways to make products integrable into larger ecosystems and making them compatible with IoT developments in the future is a possibility to raise attraction of a product and anticipate future developments.

Furthermore, cooperation and strategic partnerships hold potentials in the development phase of a product (synergy effects by combining expertise) as well as in the market introduction phase of a product (existing customer relations can be shared).

2.4.4. Threats

Established products with high quality and functionality in the areas of energy efficiency and convenience lead to customer expectations rising as well. Customers now expect a certain level of functionality which means that high scores in the areas of energy efficiency and convenience are not enough to convince customers of a product. On the contrary, these functionalities are not able to excite a consumer about a product but are much more expected as a minimum requirement.

The BEMS market presents a very competitive market which makes it necessary to always stay ahead of developments and innovations to be able to establish a product on the market lastingly.

Changing regulations occur frequently in times of high energy prices and energy transition and are hard to predict. Therefore, it is crucial to adapt to changing regulations quickly and flexibly. Furthermore, regulations might differ from region to region which makes the market introduction phase difficult. Principles that proved to be reliable in one region cannot be expected to succeed in another region in a similar way. Different climate zones demand for varying functionalities especially in the sector for indoor heating which is why products must be adapted to local needs.

Installation challenges also present a threat to new products. Consumers might prefer easier to install systems which makes it crucial to consider this aspect in the development phase. Most customers are unfamiliar with this rather new technology and need supportive measures and incentives in order to build trust.

As derived from the market assessment, most BEMS manufacturers struggle to provide flexibility, a limitation clearly reflected in the assessment matrix and the subsequent SWOT matrix. However, Smart2B services address this identified market gap by offering enhanced adaptability at the building level. By integrating advanced technologies and innovative solutions, Smart2B enables buildings to respond dynamically to changing demands and conditions, thereby improving operational efficiency and user experience.

3. Flexibility market assessment

This chapter provides a detailed evaluation of the flexibility market, focusing on the current landscape, key trends, and major players. It investigates the role of flexible energy solutions in enhancing grid stability, optimizing energy consumption, and integrating renewable energy sources.

3.1. Overview of prominent manufacturers

This section presents a comprehensive analysis of leading manufacturers in the flexibility market, highlighting their primary products, technological innovations, and strategic approaches. It covers companies that are pioneering flexible energy solutions, their market positioning, and their contributions to the energy transition.

3.1.1. GridX

GridX offers XENON, an advanced IoT platform with pre-built modules for developing decentralized energy management applications. Their business model focuses on providing an ecosystem for businesses to innovate rather than offering turnkey products. Companies can use XENON to create Home Energy Management Systems, dynamic charging systems for electric vehicles, or load optimization systems for energy communities. [71]

XENON connects, monitors and controls various distributed energy resources such as AC/DC chargers, digital meters, PV inverters, heat pumps and batteries. It standardizes different manufacturers' data formats and protocols into one API through digital adapters: this ensures interoperability, allowing any device to be controlled with the same commands, regardless of manufacturer. XENON currently supports products from 45 manufacturers, with new integrations added monthly. [72] Using XENON’s pre-built modules and standardized API, companies can develop energy management products without worrying about interoperability issues. Developers can focus on using XENON's standardized data models and protocols. The platform offers a hardware gateway, “gridBox,” for connecting resources, claimed to be the most advanced in the market, along with services for direct cloud connections. [73]

GridX provides the XENON platform to ensure product interoperability and pre-built modules to facilitate the development of energy management products, saving development time. Examples include a Home Energy Management System developed by Viessmann for peak shaving and optimizing energy flows, and a dynamic charging system created by E.ON for managing charging power based on real-time load. XENON ensures interoperability through a single API, saving developers significant time. Its modules support various flexibility types, such as load shifting and balancing, and enable dynamic energy tariffs. The platform is highly scalable, suitable for applications across sectors like logistics, residential, and commercial buildings. Continuous integration of new products further enhances its capabilities. [74]

3.1.2. Next Kraftwerke

Next Kraftwerke was founded in Germany in 2009 and operates one of the largest Virtual Power Plants in Europe, with an aggregated capacity of approximately 13,500 MW and more than 15,000 interconnected assets, including power plants, storages, and consumers. They focus on commercial and industrial buildings, targeting industrial companies, electricity generators, and power plant operators. [75]

Next Kraftwerke does the marketing on the electricity market for electricity generators, meaning they act as a power trader for producers at the Energy Exchange carrying out the balancing group management and the direct marketing for them. [76]

Next Kraftwerke enables industrial companies to sell their flexibility as balancing energy and optimizes consumption according to dynamic energy tariffs, generating remunerations and cost savings for their customers. [77]

The VPP is guided by price signals (electricity prices, selling prices for electricity and flexibility) and then sends signals to the connected assets to activate the corresponding flexibilities. This results in remuneration for the customer through the marketing of balancing energy and cost savings through the optimal adjustment of electricity consumption to dynamic energy tariffs. [78]

On the building level Next Kraftwerke is capable of shifting loads as well as of shedding and generation by adjusting consumption and production times whenever profitable. On the system level Next Kraftwerke is capable of shedding and generation by controlling connected assets according to the systems needs and with the help of connected batteries can also provide modulation functionalities.

3.1.3. Entelios

Entelios AG was founded in 2010, making it Europe's first Demand-Response provider according to their own records. The company's focus lies within the non-residential building sector, targeting industrial companies, energy suppliers and clean tech investors. [79]

Their core service consists of marketing flexibility across various flexibility markets, including the control power markets of transmission system operators and short-term trading on the European power exchange EPEX SPOT. They strategically position a customer’s flexibility on whichever market is the most profitable thus generating higher remuneration compared to relying solely on one flexibility market. They refer to this strategy of dynamically changing the place of sale as “cross-market optimization”. By applying their cross-market optimization strategy remuneration can be as much as 50% higher than when relying on a single flexibility market only. [80]

Entelios uses price signals to optimize production times (load shifting and shedding) of industrial customers thus helping to stabilize the grid and generating cost savings and remuneration when the reduction of production is sold as balancing energy. [81] Besides marketing flexibilities as automatic Frequency Restoration Reserves, Entelios also managers battery storages and sells their flexibility as Frequency Containment Reserve (modulation). [82]

3.1.4. Kaluza

They British software-as-a-service (SaaS) business Kaluza focuses on the residential building sector, mainly targeting energy retailers and the occupants of residential buildings. Kaluza's technology aims at helping energy retailers to enhance their customer services while also addressing the needs of residential building occupants. [83] According to their claims, Kaluza is responsible for the world's first and largest rollout of vehicle-to-grid charging technology, a concept that allows electric vehicles to serve as battery storage units. This enables electric vehicles not only to draw power from the grid but also to feed energy back into the grid for compensation. Kaluza states that their technology has reached 5.8 million people.

For energy retailers, Kaluza offers services such as real-time billing, intelligent grid services, and enhanced customer experiences. Their services for building owners and users of residential buildings focus on optimizing the charging and consumption of electric vehicles, HVAC systems, and batteries. [84] The Kaluza Flex platform connects millions of smart home devices, including electric vehicles, storage heaters, and home batteries and intelligently manages their charging. By optimizing when these devices charge and discharge, Kaluza Flex reduces pressure on the grid during peak times and allows more renewable energy to be used. [85]

Kaluza utilizes both price signals and signals from grid operators to activate flexibility resources. At the system level, Kaluza facilitates load shifting, while at the building level it enables electric vehicles to act as a generation flexibility resource. [86]

3.1.5. Resilience Energy

Resilience Energy, a startup headquartered in London, specializes in energy management solutions driven by their self-learning AI engine. This platform, situated between buildings and the power grid, optimizes building operations based on the learned data. The primary focus lies more on generating cost savings and profitability for building occupants than for network operators. While currently targeting residential buildings mainly (homeowners, housing providers, solar installers and energy providers), their services extend to non-residential sectors. [87]

The AI engine by Resilience Energy learns electricity consumption and generation patterns and then optimizes energy import and export according to tariffs. It coordinates generation, storage, consumption, purchase, and energy trading to maximize cost-efficiency. Additionally, it capitalizes on the flexibility of residential batteries on the flexibility market. Resilience Energy claims energy bill reductions of 20-30% through this optimization process. [88]

The AI engine activates building flexibilities according to prices signals (import and export prices for electricity), focusing primarily on the building level. This approach enables for both load shifting and generation flexibilities. Resilience Energy's platform represents an innovative approach to energy management, offering users the means to optimize energy usage and generating cost savings while also stabilizing the electricity grid.

3.1.6. E.ON

E.ON offers several services in the flexibility sector. For the residential sector E.ON provides flexible energy tariffs where electricity prices are linked to the SPOT market price. [89] For the non-residential sector E.ON also offers e-marketplaces where grid operators can buy flexibility from participating businesses. These platforms (named SWITCH and ENKO) act as aggregators and Virtual Power Plants. Thereby E.ON targets private individuals with their flexible energy tariffs in the residential sector and businesses, producing industries and grid operators with their e-marketplace platforms in the non-residential sector. [90]

E.ON’s flexible energy tariffs are especially suitable for customers with e-vehicles since they can be charged flexibly. Via an app, customers can see their current electricity price and manage their energy consumption and e-vehicle charging thus optimizing electricity expenses. E.ON’s e-marketplaces SWITCH and ENKO act as matching platforms where businesses can offer their ability to reduce or increase their electricity consumption or generation. Grid operators can log into the platform and request the flexibility to balance the grid. The platform

then sends a notification request to the business to activate the flexibility on a voluntary basis. When activating the flexibility, a financial payment takes place.

E.ON's solutions can provide shedding and generation flexibility services on a building level and by acting as an aggregator also on the system level. Their flexible energy tariffs build on electricity price signals; the e-marketplace platforms use signals from the grid-operators (e.g. grid digestion) and then determines flexibility activation request signals for the providing businesses. [90]

3.1.7. Open Energi

Open Energi specializes in marketing flexibilities of the industrial building sector, with a primary focus on battery storages, potentially augmented by solar or electric vehicle (EV) technologies. They proclaim themselves as market leaders in automated flexible energy technology. [91]

Their platform, Dynamic Demand 2.0, operates on the principle of algorithmic trading combined with machine learning to optimize energy bidding and dispatch scheduling. This enables seamless stacking and trading of flexibility. Open Energi's platform integrates battery storage and low carbon technologies, allowing for real time access to wholesale energy markets and ancillary grid service markets. It adeptly switches between different markets, including Low and High DC, Dynamic FFR, Day-ahead and Intraday, the BM, and Triads. [92]

Units connected to the platform are strategically coordinated to provide shedding and generation flexibility services. The platform operates according to price signals from various electricity and flexibility markets and enables for shedding and generation on the building level.

3.1.8. SonnenVPP

SonnenVPP specializes in marketing flexibilities of batteries (similar to open energi). Founded in 2010 in Germany, Sonnen has sold over 125,000 of its proprietary Sonnen Batteries, making it the only provider of its kind of service, according to their claims. In contrast to Open Energi, Sonnen targets private customers in the residential building sector. [93]

The SonnenVPP connects thousands of Sonnen Batteries into a virtual power plant, enabling participation in the electricity market. While a single residential battery does not meet the requirements to participate in the flexibility market, the VPP aggregates and coordinates the capacities of many individual batteries allowing their flexibilities to be sold on the flexibility market. [94]

Utilizing price signals and signals from grid operators, the VPP coordinates the flexibilities of connected batteries, enabling the provision of services at district level in shedding, generation, and modulation. When electricity is fed back into the grid from the battery, participants receive compensation based on the electricity price. Additionally, participants in the SonnenVPP receive remunerations through a profit sharing system for a duration of 10 years. [95]

3.1.9. Urban chain

Urban Chain, based in Manchester, pursues the vision "to make energy affordable for all" and builds on peer-to-peer energy trading to achieve this vision. They claim to be the leading provider of peer-to-peer energy exchange services in the UK. Their technology is utilized in

both the non-residential (e.g., hospitals, data centers, universities, office buildings) and residential building sector, with their main targeted customers being businesses, energy sellers, and private individuals. [96]

Urban Chain utilizes integrated blockchain and AI technology to match renewable energy generators with consumers on a half-hourly basis. Their technology can be used for the creation and operation of local energy markets, allowing organizations such as municipalities and local authorities to establish their own local energy markets. Companies generating renewable energy across multiple sites can aggregate this energy, use it across various locations and sell any excess. Urban Chain promises to manage all technical, operational and reporting aspects related to private energy markets. [97]

The platform operates based on price signals to match consumers with providers, providing flexibility of the type of generation at district level. Using Urban Chain's P2P energy exchange markets, consumers can achieve a 50% cost reduction, while energy generators can see a 50% increase in profit compared to traditional energy markets.

3.1.10. Voltalis

Voltalis focuses specifically on the niche market of buildings with electric heaters in France. Their business model consists in installing their intelligent thermostats, which Voltalis then controls during peak times to temporarily reduce the electricity consumption of the electric heaters. This load shedding is then sold as balancing energy. Voltalis primarily targets private individuals in the residential building sector but also serves non-residential buildings like offices and hotels. Their technology is currently limited to buildings with electric heaters, although they are working on expanding it to buildings heated by electric heat pumps. According to their claims, 200 000 homes in France have been equipped with Voltalis intelligent thermostats. [98]

Voltalis installs their intelligent thermostats free of charge, making their business model unique among the previous manufacturers. Customers do not bear any costs but receive a €50 installation incentive. In return, Voltalis can control the thermostats to reduce energy consumption during peak times, selling this load shedding as balancing energy. Customers are not directly participated in these revenues. Voltalis promises that the temporary reduction in heating does not compromise comfort. [99]

At the building level, Voltalis provides flexibility services for both load shedding and load shifting, as heating loads are reduced and subsequently shifted. Voltalis uses price signals to determine the time for activating these flexibilities. The revenue for the customer consists in the 50€ installation incentive and a free intelligent thermostat with which energy savings of up to 15% can be achieved.

3.2. Flexibility manufacturers assessment methodology

The increasing share of renewable energy sources causes greater volatility in the energy supply system, leading to the need for compensation of this volatility through flexibility. Furthermore, the decentralization of energy production necessitates a centralized coordination and complex management of the numerous producers and consumers to maintain grid

stability. Buildings and their infrastructure offer inherent flexibility, yet harnessing this potential requires tailored technologies and management systems. [100]

This section outlines the development of a framework for assessing the building flexibility among flexibility providers sector. This framework provides insights into the current status of this sector, identifying trends and potentials. It highlights how smart building technologies can unlock flexibility within the building stock and its facilities, bolstering grid stability and offering compensation benefits to building occupants for the flexibility their buildings provide.

3.2.1. Product category

Similar to the Assessment Framework for the BEMS manufacturers, the assessment framework of the building flexibility markets is also based on the analysis of individual flexibility providers and their services or products. Products are first categorized into product categories, as comparing different products is only plausible within a product category. The product categories include aggregator, EV charging, batteries, peer-to-peer energy exchange and heating. Below is a brief overview of each category.

Aggregator: Aggregators integrate smaller flexibilities into a centralized platform, forming a larger flexibility which can be marketed on the flexibility market. Within the building stock there are numerous small individual potentials for flexibility, such as heat pumps that can be intermittently switched on (load increase) or off (load shedding), or storage units, electric vehicles or small household appliances like washing machines or dishwashers. However, these flexibilities can only be utilized for grid stabilization if they are strategically controlled and managed during required times to achieve load increase or load shedding. Aggregators serve as central platformers to which these small potentials are connected to and controlled from. With sufficient aggregated capacity from small producers and consumers, the platform can participate in the flexibility market and provide the required amount of flexibility by distributing the demanded capacity among the small flexibility potentials, forming a larger tradable capacity on the flexibility market. To enable individual buildings and their facilities for providing flexibility services, products are required which unlock the small flexibility potentials and are able to connect and integrate into an aggregator. Furthermore an aggregator is needed, serving as a central platform by controlling and managing the aggregated capacities, thus generating profits for building operators on the flexibility market.

EV charging: This product category includes products specifically focused on the management and intelligent charging of electric vehicles, often targeting large charging stations in companies or commercially offered infrastructure rather than private charging stations in the residential building sector. These products may also act as aggregators but are primarily designed to optimize the charging process of electric vehicles in terms of grid stability and user costs. These products analyze charging behavior and can adjust the charging process, for example based on electricity prices and grid load, to avoid high costs.

Batteries: This category includes products that function as decentralized virtual power plants (VPP) using battery technologies. Essentially, they operate like an aggregator but specialize in battery storage. The VPP connects thousands of batteries and coordinates the individual batteries of the network, forming a larger controllable flexibility capacity. The VPP utilizes stored energy and the free capacity of the batteries to actively participate in the electricity market and stabilize the public power grid through grid services, a role previously reserved

for large power plants. With the help of the VPP, private customers can make a significant contribution to the success of the energy transition and also generate financial profits.

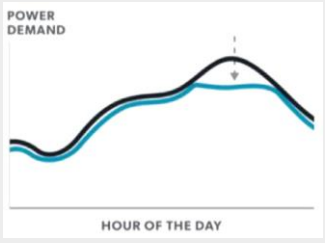
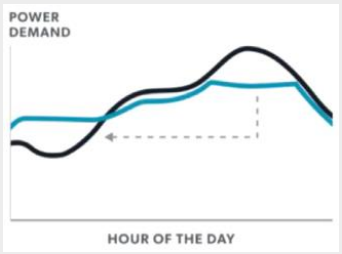
Peer-to-peer energy exchange: These products focus on the trading of electricity among decentralized consumers and producers. For example, surplus PV electricity is not sold to an electricity supplier but directly traded with a consumer, without an energy company acting as an intermediary. This allows the producer to sell electricity at a higher price than to the energy company, while the consumer receives electricity cheaper than from the energy company. Peer-to-peer energy exchange products enable this direct form of electricity trading by matching producers and consumers, managing financial transaction processes and setting the regulatory framework such as the compliance with national laws or the use of the power grid for transmission purposes.

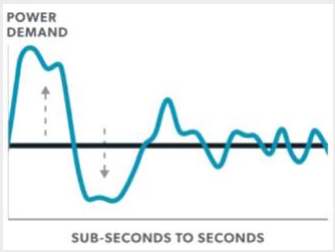
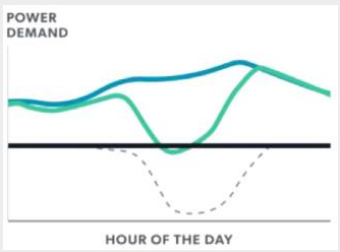
Heating: This category specifically targets products that aim to unlock and market the flexible heating potentials of a building. Heating accounts for approximately 65% of the final energy consumption in the building sector [101], indicating a high potential for energy flexibility optimizations. With the electrification of the heating system [100] the flexibility potential of the heating sector can be expected to rise in the following years, making it a meaningful source for flexibility services within the building sector.

3.2.2. Flexibility type

According to [102] there are four main types of flexibility: load shedding, load shifting, modulating and generation. This deliverable sticks to the definition of these flexibility types which are listed below. Within the assessment framework, each product is evaluated to determine the type of flexibility it provides and unlocks.

Table 5: Definition of different flexibility types [102]

Type of Flexibility	Definition	Key characteristics	Schema
Load shedding	Short-term power demand reduction during peak demand hours or emergency events	Power demand must be reduced within minutes of receiving notifications and usually last for up to one hour	
Load shifting	The building changes the energy use timing to reduce the power demand during peak demand hours or exploit renewable generation	Power demand must be reduced within minutes of receiving notifications and usually lasts for two to four hours	

Modulating	The building receives grid operator signals and automatically adjusts power demand	Power demand must be adjustable at second or subsecond temporal intervals	
Generation	The building generates electricity for on-site use or dispatch to the grid during peak demand hours	Power demand needs to be reduced within minutes of receiving notifications and usually lasts for two to four hours	

3.2.3. Application level

The category of application level captures the scope of the flexibility which is provided by a product. The kind of flexibility a product provides varies between flexibilities on building level (e.g. thermostats adjusting to the production of PV electricity) or up to the level of the whole power grid (e.g. congestion management software). Based on the categorization presented in [102] the assessment matrix distinguishes between four application levels, which are explained below: building level, district level, system level and the whole building sector.

Building level: At the building level, products focus on unlocking flexibility within individual buildings, with features such as smart thermostats adjusting operation based on PV generation. Products enabling the connection of flexibility potentials of a building to an aggregator also fall under this category, as they primarily focus on generating benefits for a single building or its occupants by unlocking local flexibility potentials rather than aiming at the generation of benefits for the supply grid. The aggregator itself on the contrary would fall under the system level since it operates on the level of the energy supply system.

District level: In contrast to the building level this application level expands to a larger number of buildings. A district refers to a community where buildings are physically located in the same neighbourhood, or a composition of buildings where the loads can be coordinated while they are not physically in the same neighbourhood. Consequently, this application level applies to products which affect a small proportion of the building stock. Peer-to-peer electricity trading products would be an example for a product falling within this category. Products of this category aim at generating revenue for individual buildings rather than the whole energy system, although they might still have positive effects on a system level.

System level: The system level refers to products designed for the energy supply system as a whole. These products operate on the grid side of the energy supply system, focusing on managing operations at the energy grid level. Examples include aggregators, which act as flexibility providers on the grid level, and congestion management software used by grid operators. Unlike products that serve individual buildings, products at this level aim to benefit the grid and the entire energy system. For instance, while a building-level product might

optimize energy use within a single building, a system-level product ensures balanced load and efficiency across the entire grid.

Building sector level: This level encompasses products designed for the entire building sector, but they focus on the building side of the energy system rather than the grid side. The primary goal at this level is to generate benefits for the buildings themselves, not the energy grid. For example, building management systems (BEMS) optimize energy consumption and improve comfort within individual buildings, while smart thermostats adjust heating and cooling based on occupancy. These products provide tangible, day-to-day benefits to building occupants, such as reduced energy bills and increased comfort, contrasting with system-level products that work to maintain grid stability and efficiency.

3.2.4. Principle of generation, business model, cost savings

These categories aim to capture the functionality of the products and their value proposition. The assessment framework describes the core operating principle and evaluates the business model through an analysis of targeted customers and the types of buildings in which the products are deployed. From this conclusion can be drawn regarding the diversity of the product range in the energy flexibility market and any potential gaps. The category of cost savings/revenue for customers attempts to quantify the benefits of the products and their value proposition for building users.

3.2.5. Flexibility activation signal

When activating a flexibility source, there are various types of signals used for the activation of the flexibility source, which are captured in this category. A distinction can be made between flexibility sources that are voluntarily activated, for which some form of compensation is necessary as an incentive, and where the building occupants have the decision to comply with the activation request, and those that are involuntarily activated, where activation requests cannot be denied. Signal types can include notifications, where operators are sent a request to activate their flexibility source within a certain amount of time, but also electricity price signals, as this will lead consumers to voluntarily reduce their consumption during peak times, thereby relieving stress on the power grid. Additionally, for involuntary activation, there may be signal types that are directly connected to the flexibility source, and upon receiving the signal, the flexibility source is activated without the occupants being able to intervene.

3.2.6. Capacity

The category of capacity quantifies the size of the managed flexibility sources of a product or platform in megawatts (MW) and allows for conclusions to be drawn about the distribution and market penetration of a product.

3.2.7. Final assessment framework

The flexibility providers are categorized according to their activity field and compared against one another. The final assessment framework we developed for a comparison of the flexibility providers can be seen in Table 6: Assessment of flexibility providersTable 6 and the results are interpreted through a SWOT analysis afterwards

Table 6: Assessment of flexibility providers

type of product			Application level				principle of operation	business model		cost savings/ revenue for customer	flexibility activation signal	capacity
	Company	Flexibility type	building	district	System	Building sector		building type	targeted customers			
Aggregator	gridX	shifting loads	x					mainly residential + EV charging	EV-charging, HEMS manufacturers, flexibility product manufacturers	developers can use pre-built moudels saving time and money	price signal, signals from grid operator	
		shedding	x	x								
		generation		x								
		modulating										
	Next Kraftwerke	shifting loads	x					Commercial & industrial	industrial companies, electricity generators/ power plant operators	remuneration for control energy; savings due to flexible energy tariffs	price signals, signals from virtual power plant	
		shedding	x		x							
		generation	x		x							
		modulating			x							
	Entelios	shifting loads	x					non-residential	industrial companies, energy suppliers, clean tech investors	50% more remuneration than when marketing on just one flexibility market	price signals, signals from TSO	
		shedding	x									
		generation										
		modulating										
	Kaluza	shifting loads			x			residential	residential buildings, energy retailers	savings due to load shifting to times with cheaper price; remunerations with vehicle-to-grid mechanisms	electricity price signals, signals form grid operator	
		shedding										
		generation	x									
		modulating										
	Resilience energy	shifting loads	x					residential	home owners, housing providers, solar installers, energy providers	20-30% on electricity bills	price signals	
		shedding										
		generation	x									
		modulating										
	E.ON.	shifting loads						residential, non-residential	private individuals, businesses, grid operators	potential saving on grid fees of up to 80%; avoiding peak electricity price times	price signals, signals form grid operator, signals from marketplace platform	
		shedding	x		x							
		generation	x		x							
		modulating										
Batteries	open energi	shifting loads						industrial	battery storages (+solar or EV)		price signals	
		shedding	x									
		generation	x									
		modulating										
	Sonnen VPP	shifting loads						residential	private customers	electricity fed into the grid is remunerated with the electricity price; profit sharing for 10 years	signals from grid operator, price signals	
		shedding			x							
		generation			x							
		modulating			x							
Peer-to-peer	Urban chain	shifting loads						residentilal & non-residential	businesses, private individuals, energy sellers	50% savings for consumers, 50% more revenue for generators	price signal (matching of consumer and provider)	
		shedding										
		generation		x								
		modulating										
heating	Voltalis	shifting loads	x					residential with electric heating; offices and hotels	private individuals, offices and hotels	up to 15% energy savings; free thermostat; 50€ starting incentivation	price signal, signals from voltalis	
		shedding	x									
		generation										
		modulating										

3.3. Flexibility SWOT analysis

In order to determine the current technological stand of the market, a SWOT analysis for the Home Energy Management Market was carried out within SMART2B project. A summary of the main findings consists of:

- **Strengths**: The flexibility providers offer comprehensive solutions across various application levels with significant financial returns and low initial investments. It is highly digitalized and leverages advanced technologies such as AI, machine learning, and blockchain.
- **Weaknesses**: There are challenges in validating flexibility services and effectively communicating with customers, alongside high market fragmentation. Moreover, Solutions specifically tailored for addressing the building sector level are limited.
- **Opportunities**: There is growing demand for renewable energy integration and increasing electrification in heating and transport sectors. In this direction, supportive government policies and incentives could also provide favourable conditions for growth.
- **Threats**: Regulatory uncertainties and differences across markets pose challenges, along with the increasing volume of data and cybersecurity threats. Furthermore, the flexibility providers are highly dependent on customer cooperation for success.
-

Table 7: SWOT analysis of flexibility providers

	Opportunities	**Threats**
	• Growing demand for renewable energy integration • Increasing electrification of heating and transport • Favourable regulatory government incentives and programs	• Regulatory uncertainties/ regulatory differences for different markets • Increasing amount of data • Cybersecurity • High dependence on customer cooperation
Strengths	S-O strategies	S-T strategies
• Solutions on most application levels • Significant remuneration and cost savings with low investment costs • High degree of digitalization • Advanced technologies (AI, machine learning, blockchain)	➢ Ensuring scalability for future rising demand ➢ Cooperation with municipalities and local authorities	➢ Development of infrastructure able to handle the increasing amount of data ➢ Increase efforts for cybersecurity ➢ Backup plans for breakdowns
Weaknesses	W-O strategies	W-T strategies

• Validation of provided flexibility services • Customer information and communication • High market fragmentation (lack of overview) • Lack of solutions on building sector level	➢ Standardization (interoperability for validation) ➢ Information programs (emphasize advantages for customers, build customer trust)	➢ Development of validation solutions ➢ Aggregation of flexibility sources not dependent on customer cooperation

In the following, we provide more information on the dynamics of different aspects of this SWOT analysis.

3.3.1. Strengths

The flexibility manufacturers assessment matrix shows that the market offers products for most of the defined application levels (building level, district level, system level, sector level). Especially for the building level there is a variety of aggregators, which are able to accumulate the flexibilities of different buildings and market the aggregated flexibility on different flexibility markets, although the established product focus more on the non-residential buildings. The same can be said about the system level where a variety of products can be found.

Concerning the different flexibility types (shifting loads, shedding, generation, modulating) most types are served on every application level (except for building sector level) and an especially high saturation for load shifting and load shedding can be observed.

The evaluated companies address different flexibility sources in both the residential and non-residential sector. For both the residential and the non-residential sector the assessment matrix reveals a high concentration of products targeting battery storages and EV-vehicles which might be due to the attractive type of flexibility these technologies provide. While most flexibility sources are only able to provide one or two types of flexibility, batteries can be used for providing each of the four flexibility types (shifting loads, shedding, generation, modulating). Within the evaluated manufacturers, modulating services are only provided in combination with battery technologies.

The high remuneration with relatively low investment costs might be the biggest strength from the customer perspective. Most manufacturers promise significant cost savings or additional profits (around 15% with some as high as 50%) while comfort or industrial processes are hardly affected negatively. Some business models don’t even comprise any investment costs at all, e.g. the company Sonnen even pays their customers if they are willing to make their batteries available for the Virtual Power Plant of Sonnen.

Furthermore, the evaluated products make use of highly advanced technologies with AI, machine learning and blockchain being applied. The state of the flexibility market can be described as highly digitalised.

To conclude, the flexibility market has a high saturation with products for different application levels and flexibility types, offering diverse and individual solutions with advanced technologies.

3.3.2. Weaknesses

One significant weakness in the validation of provided flexibility services is exemplified by platforms such as Crowd Balancing, which prioritize validating flexibility services to ensure and prove that purchased or agreed flexibilities are actually fulfilled and delivered. Another weakness lies in customer information and communication; customers may not fully understand the operational principles, which can hinder the effectiveness of the service. Additionally, the adoption of these services is not as widespread as the non-residential level, indicating a lack of effective communication and engagement in this sector. Furthermore, the modulation at the district level is relatively minimal, though this observation might be limited by the small selection of companies considered in this analysis.

3.3.3. Opportunities

Opportunities are driven by the growing demand for renewable energy integration and increasing electrification in heating and transport sectors. Batteries in electric vehicles and heat pumps can be used as flexibility assets, especially with batteries being able to provide any kind of flexibility service. Heat pumps can be switched of for short amounts of time without negatively affecting comfort and thus could potentially provide a source for load shedding. In order to activate the flexibility potentials of e-vehicle batteries and heat pumps a targeted coordination will be essential. Existing government incentives for electric vehicles and heat pumps will further drive the uptake of these technologies, thus accelerating the electrification of these sectors.

The growing demand for and integration of renewable energy sources will inevitably lead to increased volatility in the electricity grid. This necessitates a complex balancing of the grid thus generating market demand for solutions reducing grid management costs and intelligently managing electricity distribution. With the integration of IoT and industry 4.0, solutions being capable of intelligently using the aggregated data to improve gird operation will be needed. An open space for innovation and optimization is evolving.

3.3.4. Threats

A significant threat identified in many flexibility solutions is their high dependence on customer cooperation. Most systems require active participation and willingness from customers to activate and utilize the flexibility services. Only a few companies, such as SonnenVPP and Voltalis, have developed systems that operate independently of customer willingness, thereby reducing this dependency. This reliance on customer cooperation can significantly impact the effectiveness and reliability of the flexibility solutions offered by most providers. Hurdles hindering customer participation might be poor communication with customers or scepticism towards new technologies and the unpredictability and insecurities coming with them. Good communication will be key to building trust in these new technologies.

The increasing amount of data also needs to be addressed by developing infrastructure capable of handling such amounts. The infrastructure coordinating smart building solutions needs to keep up with the uptake of such technologies since the full flexibility potential can only be exploited in combination with appropriate coordination. A mere uptake of smart technology without centralized coordination should be avoided since the existence of smart technology alone does not bring about improvements for the grid flexibility, but only when the existing smart technology is used and activated in an efficient way.

Regulatory uncertainties and differing regional legal requirements might also propose a challenge. Regulatory frameworks might change in favor of but also in opposition to the uptake of flexibility solutions.

Cyber security can also be seen as a threat. A major incident concerning cyber security would not only drastically decrease trust in flexibility technologies but might also cause severe damage to existing infrastructure. A neglection of cyber security in the development of flexibility solutions should be avoided.

4. SRI assessment of the EU market

This chapter provides an overview on the level of the Smart Readiness Indicator (SRI) across the European Union market. It delves into the current state of building smartification, examining the extent to which buildings are equipped with smart technologies that enhance their energy efficiency, user comfort, and overall functionality. By evaluating a representative sample of buildings, this chapter aims to present a general overview of the smartification landscape within the EU.

4.1. Smartification Rate

To determine the smartification rate of the current building stock, an SRI calculation was carried out for 12 representative buildings in 6 different countries. This assessment involved a detailed questionnaire based on original SRI calculation sheet, designed to characterize the residential and non-residential buildings in the national building stock of the various EU countries and evaluate their smart-readiness level.

The questionnaire comprised 54 questions spanning nine service sectors of the Smart Readiness Indicator: heating, cooling, domestic hot water, ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging, and monitoring/control. Respondents were asked to envision a nominal building of a specific usage (residential or non-residential) that best represents the average Building Automation and Control System (BACS) within their country and then specify the level of functionality of the smart solutions in that nominal building. Afterwards, several experts in the BACS area were contacted via email or individual online meetings, to help them understand the goal of the task and fill the questionnaire more accurately.

The results of the responses of the experts, was later transferred to the SRI calculation sheet and varying degrees of smart technology adoption and readiness across the sampled buildings were calculated. The result of these calculation is highlighted in the table below and along diagrams in this section. This analysis provides valuable insights into the progress and challenges associated with building smartification in different regions of the EU.

Table 8: results of SRI assessments in different countries.

Country	SRI score non-residential	SRI score residential
Spain	6.2%	1.9%
Portugal	3.7%	12.1%
Sweden	55.9%	Not available
Denmark	46.8%	16.9%
Austria	18.9%	39.9%
Germany	26.8%	18.6%
Belgium	Not available	21.1%

Greece	Not available	23.5%

The overall results of SRI assessment highlight the following:

- The SRI Score varies significantly across countries, indicating the adoption level of smart technologies in both non-residential and residential sectors.
- **Spain** and **Portugal** have comparatively lower SRI scores, indicating a lower adoption rate of smart technologies, especially in residential areas.
- **Sweden**, **Denmark**, **Austria**, and **Germany** show higher SRI scores, implying a more advanced adoption of smart technologies, particularly in Austria and Germany's residential sectors and Sweden's and Denmark's non-residential sector.

In the following sections, we analyze these findings in more details.

4.2. Residential-Impact scores

Germany's assessment of the seven impact criteria is relatively high among countries and stable that maintained at 40%~60%. It stands out in "Energy flexibility and storage", "Convenience" and "Information to occupants". Especially in "Convenience", it achieved a score of 67.7%. This means that residential buildings in Germany generally have amenities such as easy access, parking facilities, entrance design.

Austria is second only to Germany in terms of performance, and it scores higher than Germany in terms of "Energy efficiency", "Comfort" and "Health, well-being and accessibility". Buildings in Austria excel in energy use and may have adopted a range of energy-saving measures and technologies, such as smart energy management systems. This helps to reduce energy consumption, lower carbon emissions, and improve the sustainability of buildings. At the same time, these buildings also provide good indoor comfort, including the right temperature, humidity, and ventilation, as well as a comfortable lighting and sound environment. This can improve the quality of life and productivity of the occupants. The indicator of "Health, well-being and accessibility" means that Austria's buildings are designed and equipped with the health, well-being, and accessibility needs of residents and users in mind. This may include accessibility facilities that are easy to access and accessible, a healthy and friendly indoor environment, comfortable interior space design.

Germany, Denmark, and Belgium are also assessed favorably. Belgium has a good performance in the criteria of "Energy flexibility and storage" compares with several other countries. Belgium is likely to focus more on renewable and low-carbon energy sources in its energy mix, so the need for energy flexibility and storage is even more urgent. This has led them to be more aggressive in the adoption of energy storage and smart energy management technologies.

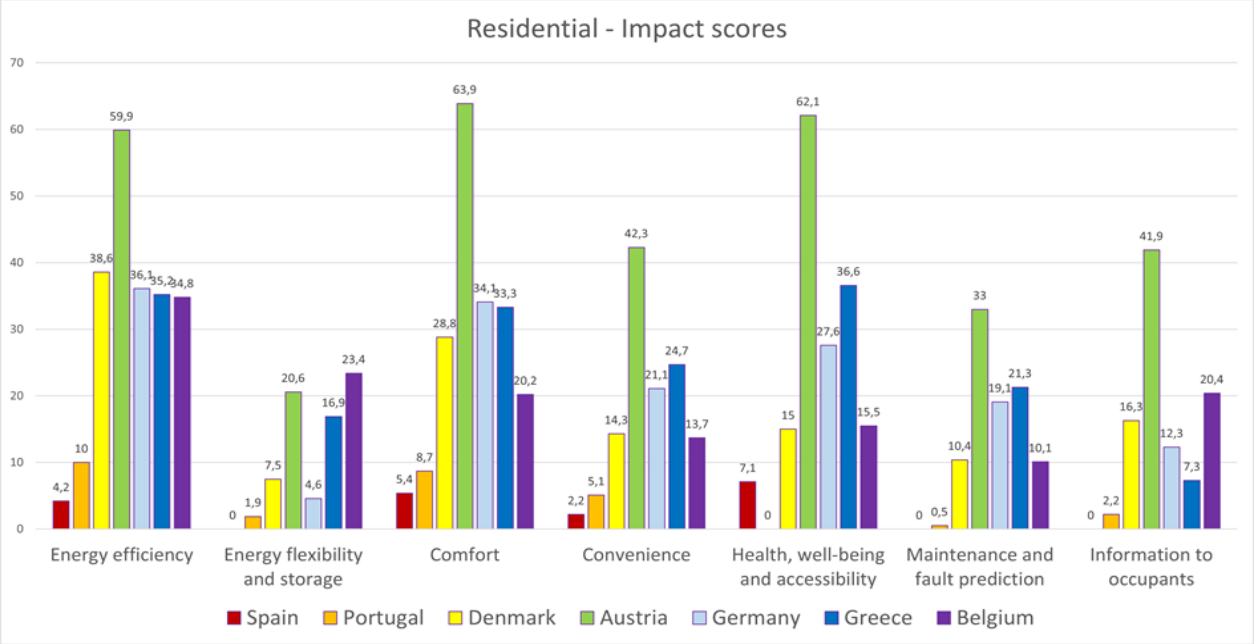


Figure 5: SRI impact score evaluation of residential buildings in different countries

4.3. Residential-Domain scores

In nine technical domains, the traditional technical domain such as "Heating"," Domestic hot water" and "Lighting" scored better on the assessment in several countries.

Austria is assessed by the experts to have the best performance in different technical domains of SRI. It is worth noting that, in addition to the traditional technology domains, Austria is also in a leading position in several automation technology domains of "Dynamic building envelope", "Ventilation" and "Monitoring and control". Especially in the domain of "Ventilation", the assessment value is 60,6 percent, well ahead of other countries. Austria has excellent technical and application competence in this field. This may include efficient air exchange systems, intelligent ventilation control and indoor air quality management. That reflects the efficiency of Austria's energy use and could also explain why Austria is the most energy efficient.

In the domain of "Electric vehicle charging", most of the countries' assessments are not good, but Denmark performs well. Most countries may have problems with EV charging infrastructure, such as an insufficient number of charging stations, slow charging or uneven distribution. These negative values indicate lack of infrastructure, as well as deficits in policy and regulations promoting the development and adoption of EV charging infrastructure. This may have hindered the penetration and use of electric vehicles in these countries. Denmark may have made significant investments and developments in this area. The Danish charging network is likely to be more sophisticated, with more charging stations, more evenly distributed and with more advanced charging technology.

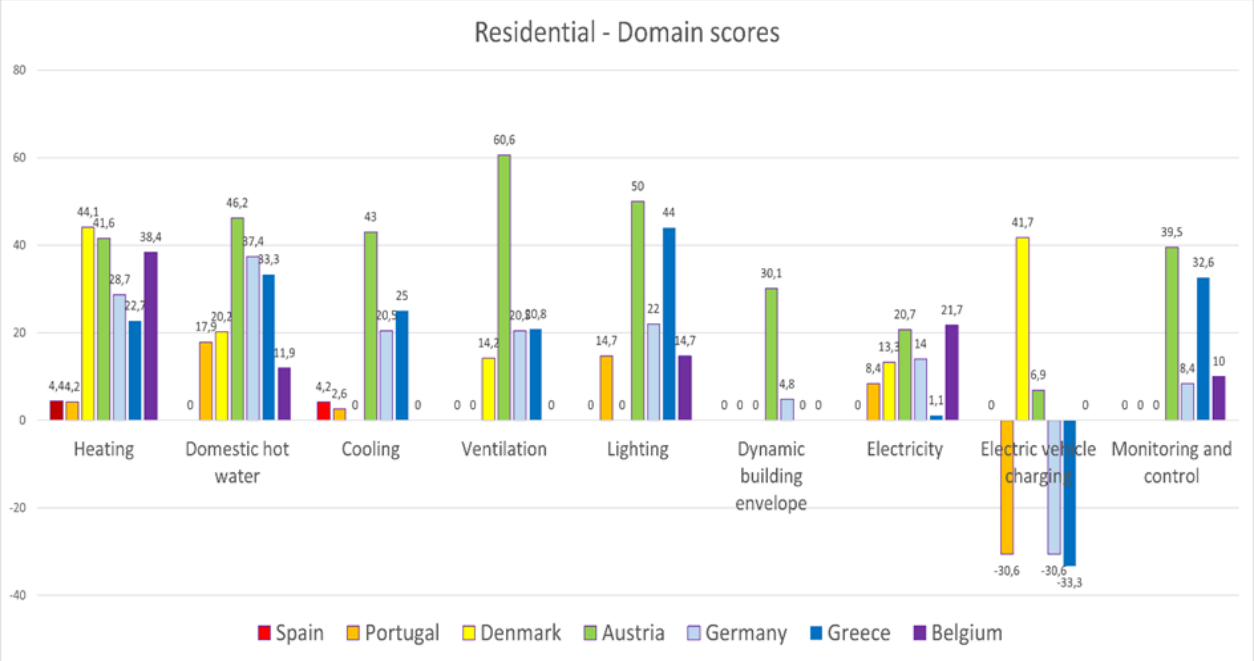


Figure 6: SRI domain score evaluation of residential buildings in different countries

4.4. Non-Residential-Impact scores

Non-residential buildings in various countries are assessed relatively higher than residential buildings in the seven impact criteria. Countries are assessed relatively well in the criteria of "Energy efficiency", "Comfort", "Health, well-being and accessibility".

Sweden is the stand-out performer. The results of its assessment remained at 50%~70%. Its assessment of "Energy flexibility and storage" is significantly higher than that of other countries. Sweden is likely to focus more on renewable and low-carbon energy sources in its energy mix, so the need for energy flexibility and storage is even more urgent. This has led them to be more aggressive in the adoption of energy storage and smart energy management technologies.

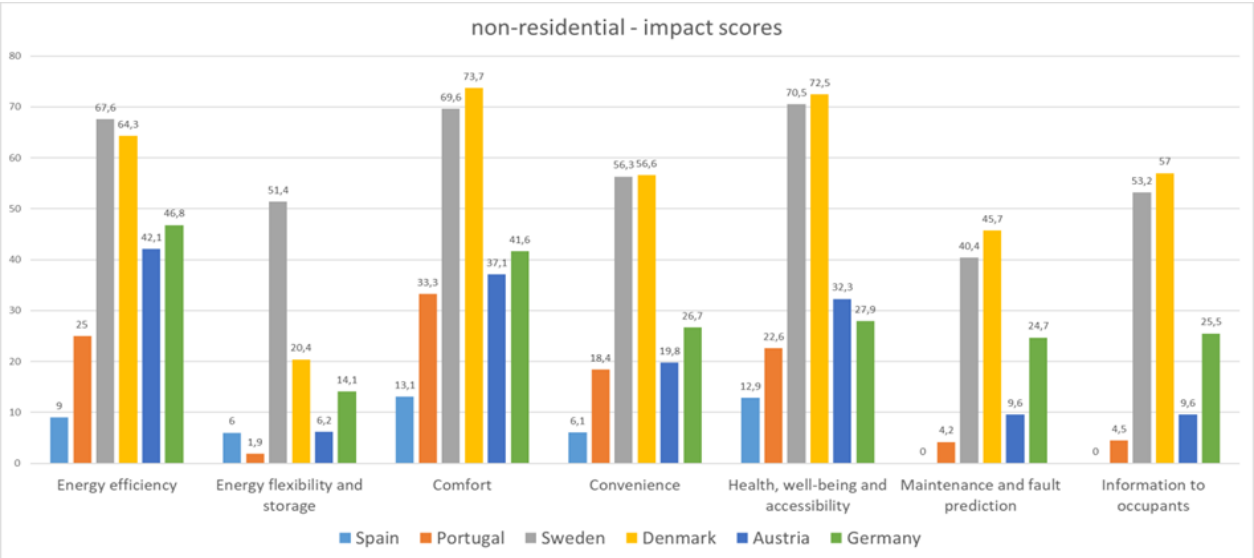


Figure 7: SRI impact score evaluation of non-residential buildings in different counties

4.5. Non-Residential-Domain scores

For the non-residential buildings, countries are still paying more attention to traditional technology domains of "Heating", "Ventilation", "Lighting".

In addition, Switzerland, Denmark and Germany performed well in the criteria of "Monitoring and control", while other countries scored lower. These countries may have a high level of development and application of intelligent monitoring and control technology. These countries are likely to invest in advanced building automation systems, smart sensors, and data monitoring technologies that will allow them to more effectively monitor and control energy use and environmental conditions inside buildings. Portugal has always been on the low end of the spectrum, however, its assessment value in the technical domain of "Lighting" is relatively higher than other countries.

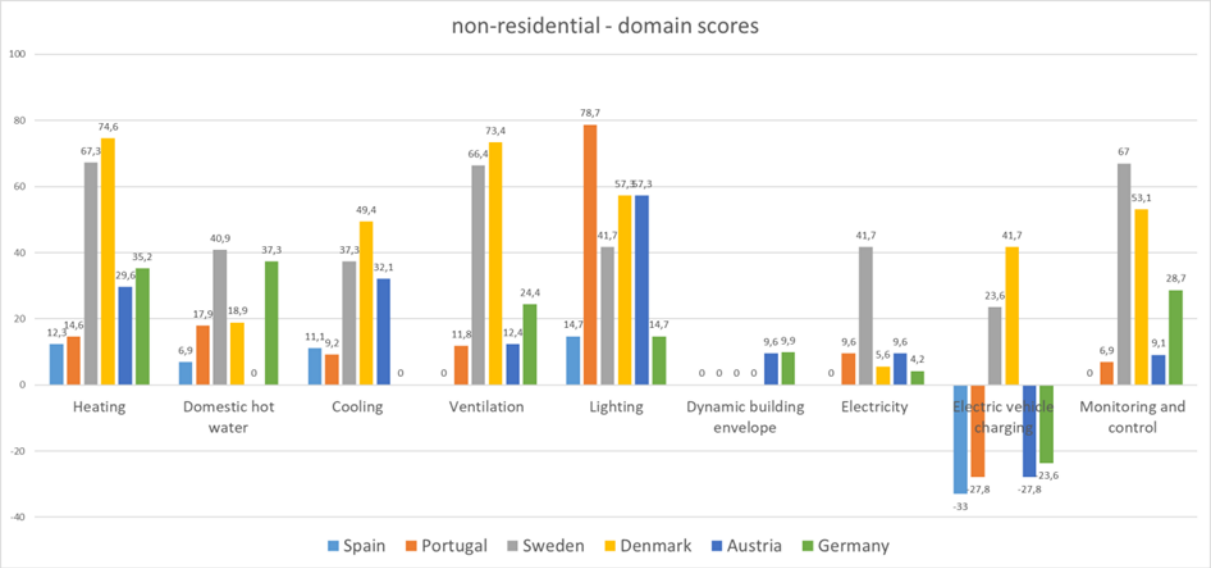


Figure 8: SRI domain score evaluation of non-residential buildings in different counties

Combined with the above analysis, the assessment results of non-residential buildings are relatively higher in non-residential countries than in residential buildings. Compared to the residential buildings, it is vivid that more levels of automated functionality are deployed in the non-residential buildings, which mainly revolve around lighting, ventilation, heating and monitoring. In Portugal and Spain, the assessment results for both residential and non-residential buildings are relatively low. There is still a lot of space for development of smart buildings in these two countries.

5. Creation of market scenarios

This chapter presents the methodology and the assumptions defined to create different market scenarios, which will be used under Task 7.4 - Cost Benefit Assessment of the SMART2B Concept to verify the sensitivity of the assumptions for sSmart2B's anticipated market penetration dynamics.

5.1. Indicators for cost-benefit-assessment (CBA)

Based on the works already developed in T.4, the Cost-Benefit-Assessment (CBA) will require projections for the following indicators in combined market scenarios.

5.1.1. Energy market

- Electricity price in €/kWh
- Feed-in tariff (PV) in €/kWh (PV plants in Smart2B provide between 1.2 and 10 kWp)
- Flexibility market (DSO) participation in €/MWh
- CO_2 price in €/kgCO_2

5.1.2. Conventional building renovation

- Shallow renovation of the building shell, cost in €/m^2
- Energy savings with shallow renovation in %
- Deep renovation of the building shell, cost in €/m^2
- Energy savings with deep renovation in %

5.2. Energy market CBA-indicators baseline and projections

Russia's invasion of Ukraine has significantly impacted the European Union's energy sector. In 2022, the EU's expenditure on energy soared, with payments for natural gas imports tripling compared to the average of the previous five years.[103] In response to this energy crisis, the EU has increased its clean energy ambitions and prioritized energy security in its transition plans. As a result, energy market forecasts published before 2021 are likely outdated and should not be used for future assessments.

The key policy initiatives in the European Union are the European Green Deal (Fit for 55), REPowerEU and the Net Zero Industry Act. `Fit for 55´ is the implementation framework for the European Green Deal, supported by the Renewable Energy Directive, Energy Efficiency Directive, EU Emissions Trading System reform and Carbon Border Adjustment Mechanism. `REPowerEU´ sets out a pathway to cut reliance on Russian natural gas via energy savings, diversification of supply and accelerated roll out of renewable energy. The `Net Zero Industry Act´ aims to boost clean energy technology manufacturing, targets technology areas such as solar and wind, bioenergy, hydrogen, CCUS, battery storage, grids and heat pumps.[103]

Baseline for CBA-indicator `electricity price´

Overview

Table 9 shows electricity prices with and without taxes and levies for households and without taxes for non-households in the participating countries in the Smart2B project.

Table 9: Electricity prices for households in €/kWh for different countries including taxes

	EU	Spain	Portugal	Sweden	Denmark	Austria	Italy	Greece	Germany	Belgium
Year	2023	2023	2023	2023	2023	2023	2023	2023	2023	2023
Electricity prices for households with taxes in €/kWh	0.2937	0.2454	0.2071	0.2662	0.3811	0.2653	0.3782	0.2327	0.4125	0.4350
Reference	[105]	[105]	[105]	[105]	[105]	[105]	[105]	[105]	[105]	[105]
Electricity prices for households without taxes in €/kWh	0.2089	0.1826	0.2903	0.1017	0.1645	0.2587	0.3124	0.3231	0.2516	0.2495
Reference	[106]	[106]	[106]	[106]	[106]	[106]	[106]	[106]	[106]	[106]
Electricity prices for non-households without taxes in €/kWh	0.1848	0.1501	0.1987	0.0774	0.1364	0.2116	0.2144	0.2531	0.1871	0.2162
Reference	[107]	[107]	[107]	[107]	[107]	[107]	[107]	[107]	[107]	[107]

After a significant price increase that began before the Russian invasion of Ukraine and had its high point in the second half of 2022, electricity prices slowly stabilized again.

In the first half of 2023, average electricity prices for households in the EU continued to rise compared to the same period in 2022, from 0.253 €/kWh to 0.289 €/kWh. In 2023, the average electricity price in the EU was 0.2937 €/kWh.

5.2.1. Projection for CBA-indicator 'electricity price'

Electricity is central to the global energy transition, driving innovations and strategies in both supply and demand sectors. This transition involves a dynamic interplay between renewables and conventional power sources, leading to changes in consumption patterns, investment flows, and technological advancements, which shape the future of global energy dynamics and environmental sustainability. Based on the current forecasts, electricity prices in the European Union for household and industrial consumers are expected to show varying trends up to 2050, influenced by the transition to renewable energy, regulatory changes, and market dynamics.

Short-term Forecast (2023-2030)

In the short term, electricity prices are expected to remain high due to existing market conditions and rising CO_2 prices. The increased integration of renewable energy sources, such as wind and solar, will gradually impact the market. From 2030 onwards, higher CO_2 prices and increasing electricity demand, especially from more flexible uses, are expected to drive up power prices. However, the expansion of wind and photovoltaic (PV) plants will help to moderate these increases, resulting in many hours with low or even negative power prices. Countries with slower renewable energy expansion may experience higher electricity prices compared to those investing heavily in renewable infrastructure. [103]

The World Energy Outlook differs between two scenarios: the Stated Policies Scenario and the Announced Pledges Scenario (APS). The Stated Policies Scenario (STEPS) provides an outlook based on the latest policy settings, including energy, climate, and related industrial policies. The Announced Pledges Scenario (APS) assumes all national energy and climate targets made by governments are met in full and on time.[103]

The impact of the current European measures is already evident in the STEPS scenario. Oil and gas demand is projected to decrease by 15 % by 2030 from 2022 levels, while coal demand is expected to drop by 55 %. Renewables are anticipated to constitute two-thirds of electricity generation by 2030, up from 39 % in 2022. Wind and solar PV are expected to account for over 85 % of the new capacity built during this period. The share of electricity in total final energy consumption is projected to reach 25 % by 2030, compared to 21 % in 2022.[103]

In the APS scenario, the more ambitious targets of the EU Fit for 55 package are largely achieved. This ensures a 55 % reduction in GHG emissions by 2030 relative to 1990 levels and meets the REPowerEU goal of eliminating dependence on Russian natural gas before 2030. Achieving these targets requires a 20 % increase in renewables deployment compared to the STEPS scenario in 2030. Electrification of the energy economy in the European Union occurs in parallel with the decarbonization of the power sector. The share of electricity in total final energy consumption is nearly 30 % by 2030, up from 21 % in 2022. Additionally, demand for heat in the buildings sector is significantly electrified, with more than 330 GW of heat pumps deployed by 2030 in the APS.[103]

The World Energy Outlook estimates electricity costs for 2030 are shown in **Table 10**. The exchange rate is 1 USD = 0.92 €.[103]

Table 10: World Energy Outlook electricity price prognosis for the EU for 2030 for different scenarios [103]

Scenario	Electricity price prognosis for 2030 in USD/MWh	Electricity price prognosis for 2030 in €/kWh
Stated policies scenario	108	0.9930
Announced pledges scenario	106	0.9741

Mid to Long-term Forecast (2030-2050)

From 2030 to 2050, the overall trend suggests that real power prices will stabilize. Despite the initial rise due to higher commodity and CO_2 prices, the continuous increase in renewable energy capacity is expected to have a dampening effect.

By 2050, renewable energies are expected to account for approximately 76 % of electricity generation in the EU according to the World Energy Outlook. The increase in wind and solar power capacity, along with the reduction in fossil fuel use, particularly coal, will fundamentally transform the electricity market landscape. This transition will likely lead to more stable and potentially lower prices in the long run, as technologies mature, and economies of scale are achieved. [103]

In the STEPS scenario, EVs will account for 55 % of electricity demand growth by 2050, resulting in 85 % of vehicles being electric and 200 million electric cars on the road by 2050, compared with around 6 million in 2022. Additionally, the energy intensity of the building stock is expected to improve by about 30% per square meter by 2050.[103]

Electric vehicles (EVs) will be even more prevalent in the APS scenario, accounting for nearly 90 % of vehicles on the road by 2050. The energy intensity of the building stock will improve by almost 50 % per square meter in the APS scenario by 2050.[103]

The World Energy Outlook estimates electricity costs for 2030 are shown in Table 10. The exchange rate is 1 USD = 0.92 €.[103]

Table 11: World Energy Outlook electricity price prognosis for 2050 for the EU for different scenarios [103]

Scenario	Electricity price prognosis for 2050 in USD/MWh	Electricity price prognosis for 2050 in €/MWh
Stated policies scenario	58.75	54.01
Announced pledges scenario	55	50.57

In **Error! Reference source not found.** drivers of natural gas demand reduction and import need in the European Union by the World Energy Outlook scenarios are shown.

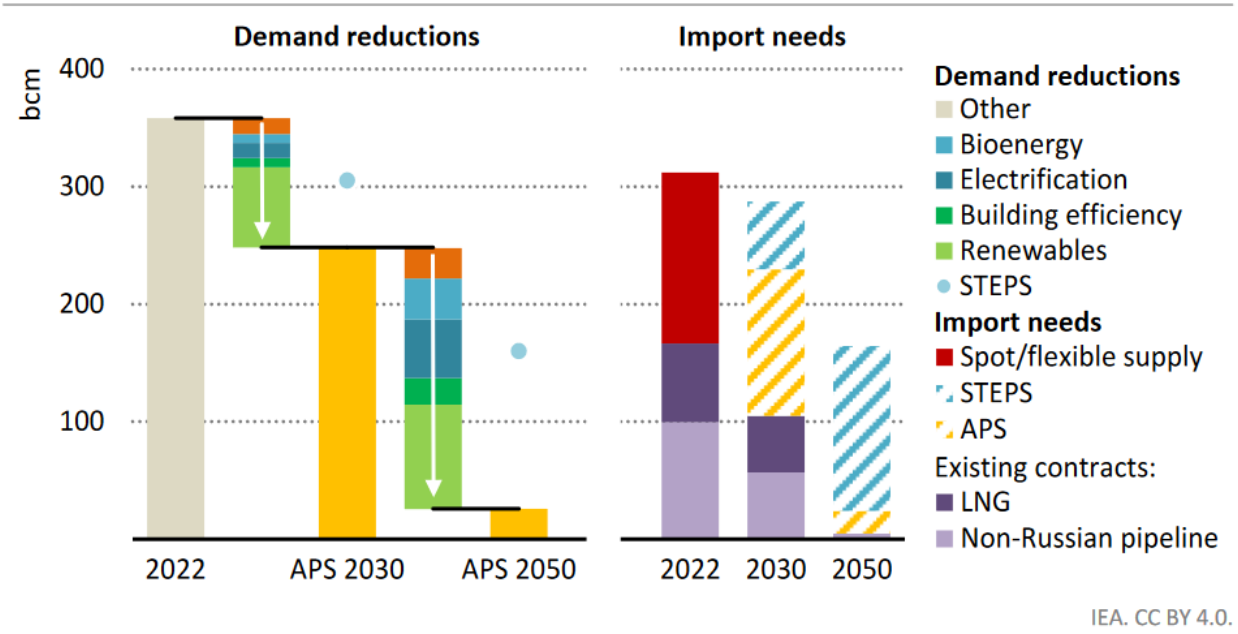


Figure 9: Drivers of natural gas demand reduction and import needs in the European Union by World Energy Outlook scenarios STEPS and APS [103]

The DNV predicts that electricity prices will demand above stagnation. This publication is based on the World Energy Outlook and combines it with other sources. According to the DNV Energy Transition Outlook in Europe, the annual growth rate for electricity demand is projected to be 2.4 % until 2050, lower than the global average due to high electrification rates and modest economic growth. However, new electricity-consuming sectors, such as transport and hydrogen production, will ensure continued growth in electricity demand above stagnation levels even by 2050. The growth rate for electricity demand is shown in **Figure 10**.[108]

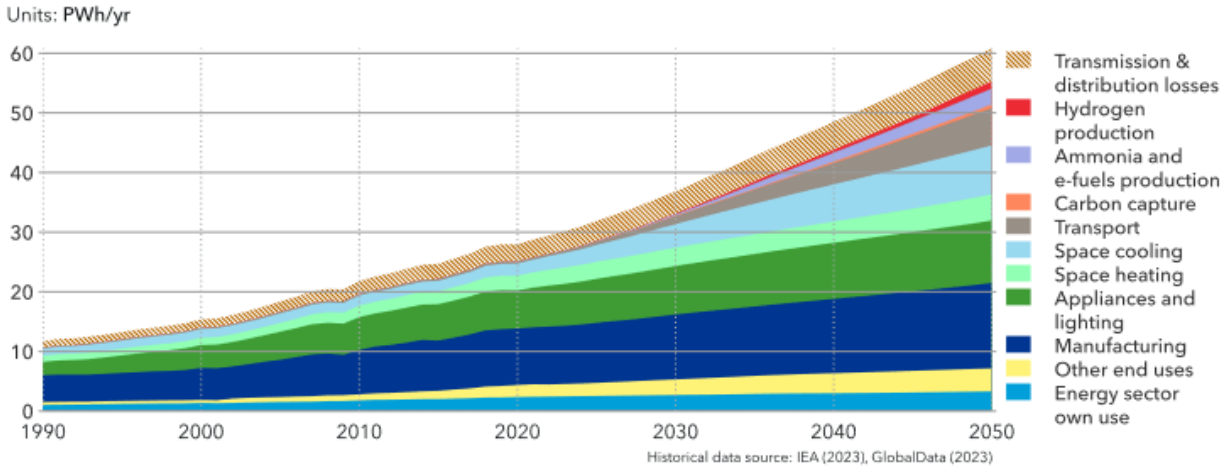


Figure 10: World annual electricity demand by segment

Variability

The projections indicate significant variability between different EU countries, driven by the pace of renewable energy adoption and local market conditions.

Addressing peak electricity demand trends is crucial, as it significantly impacts power generators and the regional transmission and distribution grids. We need to enhance grid

infrastructure to effectively transfer peak power from generators to consumers. The load factor, the ratio of average load to peak load, illustrates the consistency and variability of electrical load. In 2022, the global load factor was 78 %, projected to decrease to 76 % by 2050,[108] indicating peak load growth outpacing average demand and increasing variability. Renewable energy integration, particularly wind and solar, increases generation variability, but advancements in energy storage and grid management will mitigate these effects. The rise of electric vehicles (EVs) will redefine demand patterns, with potential variability from concentrated EV charging balanced by vehicle-to-grid flexibility. Innovations in demand-side management, such as smart grids and real-time pricing, will help reduce peak demand and promote balanced consumption. Additionally, improvements in energy efficiency will lead to steadier electricity usage, impacting the load factor.

Price Volatility

There will be an increase in price volatility due to the intermittent nature of renewable energy sources. Seasonal and weather-related fluctuations will become more pronounced, with higher prices in winter due to increased demand and lower prices in summer when solar generation peaks.

5.2.2. Baseline for CBA-indicator 'feed-in tariff (PV)'

Overview

Table 12 shows the feed-in tariffs for photovoltaic (PV) systems up to 10 kW_{peak} in the participating countries in the Smart2B project.

Table 12: Feed- in tariff in €/kWh for different countries

	Spain	Portugal	Sweden	Denmark	Austria	Italy	Greece	Germany	Belgium
Feed-in tariff [€/kWh]	0.060-0.080	0.020-0.130	0.040-0.065	0.062	0.050-0.240	0.171-0.182	0.095-0.115	0.081-0.129	0.103-0.204
Year	2023	2024	2024	2024	2024	2024	2024	2024	2024
Reference	[112]	[113]	[113]	[114]	[115]	[115]	[116]	[115]	[115]

Spain

Spain abolished fixed governmental feed- in tariff in 2013.[117] Since then, the same energy supplier that supplies the building with electricity has paid for the electricity fed into the grid. For every kWh that is fed into the grid, the energy supplier grants a discount on the energy bill. The energy bill cannot be less than 0 €/kWh, which means that homeowners cannot earn any money with their photovoltaic system, only make savings on their energy bill. Some energy suppliers offer dynamic models where the payment is linked to the market price or where the payment depends on the time of day the energy was fed into the grid. Other

providers offer fixed compensation rates that are independent of the time of feed-in. Homeowners can expect compensations of approximately 0.060-0.080 €/kWh.[118]

Portugal

In Portugal there are two different schemes for homeowners to install solar panels. The first one is called UPP (Unidades de Pequena Produção) which are small production units which sell all the produced energy to the grid. Energy produced with a UPP cannot be used for self-consumption, but all the energy produced is fed into the grid. The second scheme is called UPAC (Unidade de Produção para Auto-Consumo) which are production units which produce solar energy mainly for self-consumption purposes. Surplus energy which is not self-consumed can be sold although the remuneration schemes differ between UPP and UPAC.[119]

There are different ways for UPAC to sell the surplus energy and depending on the remuneration systems, the remuneration for energy fed into the grid varies greatly. The remuneration is also dependent on dynamic market prices. Assuming the energy is traded according to the market price with a penalty of 10 % on the market price, owners can expect a remuneration of 0.020-0.130 €/kWh.[112]

Concerning UPPs there are also several ways to trade the produced energy. It is distinguished between "General remuneration" and "Guaranteed remuneration". The guaranteed remuneration guaranties a fixed feed in price for the length of 15 years. This fixed feed-in tariff is determined in a bidding model based on a reference price.[112]

Sweden

In Sweden homeowners can expect several remunerations when feeding excess solar electricity from their residential PV-system into the grid. A tax reduction of 0,060 €/kWh is granted which can be seen as a different form of feed in rate.[120] Furthermore a remuneration from grid operators can be expected which lies around 0,002-0,010 €/kWh and varies between different grid owners and grid areas.[121] In addition to that, homeowners receive the remuneration from the electricity trader which they sell the energy to. These compensations lie around the price of the Nord Pool Spot market or can be even higher than that. This is because Swedish households usually buy more electricity from the grid than they inject into it so electricity traders offer homeowners contracts to buy excess solar energy and this way secure clients.[121] The average Nord Pool Spot market price in 2023 was around 0,040-0,065 €/kWh differing by region.[113]

Denmark

Denmark has a net metering system which operates on an hourly basis.[122] This means that the difference between the electricity fed into the grid and the electricity drawn from the grid is calculated every hour. If more electricity is consumed than generated, the homeowner is required to pay the difference[110], with the electricity price standing at approximately 0.380 €/kWh.[104] In 2024, the feed-in tariff is 0.062 €/kWh.[113]

Austria

In Austria there are two different ways to sell excess solar energy. The first option is the feed-in tariff from OeMAG (Abwicklungsstelle für Ökostrom AG), a national processing and

administration centre for green electricity. The second option is to sell the excess solar electricity to electricity providers.[123]

The feed in rate from the OeMAG is calculated quarterly and is highly volatile. In January 2024 the calculation mechanism changed meaning that the average expected remuneration decreases. For the first quarter of 2024 remuneration between 0.0578 and 0.963 €/kWh can be expected when choosing the OeMAG feed-in tariff.[124]

When selling solar electricity to electricity suppliers, remuneration lies between 0.05 and 0.240 €/kWh.[114] Most electricity suppliers only buy solar electricity from private rooftop PV systems when the customer also has a consumption contract with the supplier. Some suppliers offer contracts where the remuneration is linked to current market prices whereas others guarantee fixed prices.[123]

Italy

Italy distinguishes between a standard feed-in tariff and a standard tariff for self-consumption of PV systems. A distinction is also made between systems that are mounted on the roof and those that are mounted on the ground. A distinction is also made between the size of the systems. Only systems up to 10 kWh are considered here. The remuneration for these systems is between €0.171-0.182/kWh, depending on the tariff and type of installation.[115]

Greece

In 2014, the Greek government introduced a series of measures that significantly reduced the incentives for solar power producers retroactively. As a result, all PV systems that had been in operation for less than 12 years in January 2014 have two options after the current power purchase agreements expire: They can sell the electricity they generate on the energy market at any price or feed the energy they produce into the grid at a fixed price of 0.080 €/kWh.[115]

The feed-in tariff continues to differ between the mainland and the Greek islands. Only the feed-in tariff for systems up to 10 kWh is considered here. The feed-in tariff for this is between 0.095-0.115 €/kWh, depending on the type of installation and location.[115]

Germany

The solar feed in rate in Germany works as follows. For residential photovoltaic systems a fixed feed in rate is guaranteed for a duration of 20 years. It is distinguished between systems for self-consumption where only excess electricity is sold to the grid and systems without self-consumption where the whole amount of electricity produced is sold to the grid. The feed in rate for systems without self-consumption is higher than for systems with self-consumption. Furthermore, the feed in rate depends on the capacity of the installed photovoltaic system. Systems with a maximum capacity of 10 kWp registered between February and July 2024 receive a feed in rate of 0.081 €/kWh for self-consumption systems or 0.129 €/kWh for systems without self-consumption. This feed in rate is guaranteed for a duration of 20 years.[116]

Belgium

Since a change in the regulations in 2020 solar energy can be sold to electricity suppliers who offer varying tariffs for buying this excess energy.[125] A digital meter which is capable of measuring the exact amounts of electricity consumed and injected into the grid is a pre-

condition in order to be able to enter a contract with an electricity supplier to sell excess electricity to them. Some electricity suppliers also demand a bilateral contract, meaning that they only buy excess electricity from customers who also have a consumption contract with them.[126] Depending on the region in Belgium (varying regulations between Brussels, Flanders and Wallonia) customers can expect remunerations between 0.204 €/kWh and 0.520 €/kWh fed into the grid.[115] Some electricity providers offer contracts where the remuneration differs between day, night and weekend whereas other contracts guarantee a fixed remuneration independent of the time of day the electricity is fed into the grid.[126]

5.2.3. Projection for CBA-indicator 'feed-in tariff (PV)'

Based on current forecasts, the feed-in tariffs for photovoltaic systems (PV) in the European Union show varying trends up to 2050, influenced by the transition to renewable energy, regulatory changes, and market dynamics.

The feed-in tariff is a financial incentive for the installation of PV systems. The feed-in tariff depends directly on the expansion of PV systems and thus the available PV capacity. The higher the PV capacity, the lower the feed-in tariff. In the following, the PV capacity is therefore primarily used. The PV capacity forecast can then be used to draw conclusions about the change in the feed-in tariff.

Short-term Forecast (2023-2027)

The expansion of photovoltaics was forecast in the EU Market Outlook for Solar Power (2023-2027) report in the short term. According to this report, PV capacity will increase over the years. A distinction is made between three scenarios: a low, a medium and a high scenario. These scenarios and their respective forecasts are shown in Figure 11.[127]

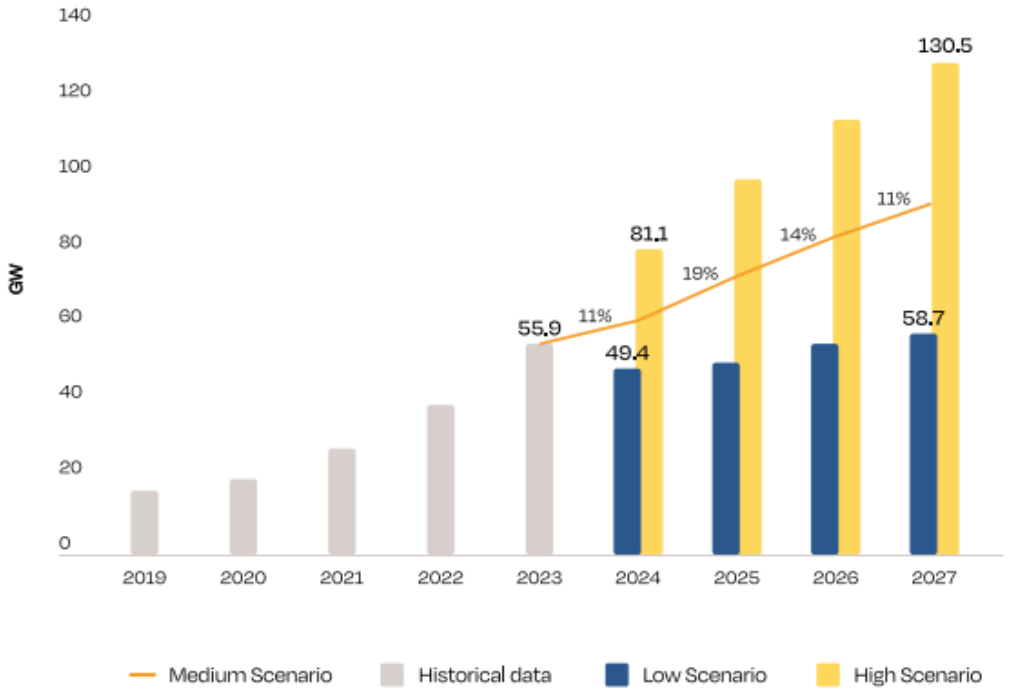


Figure 11: Annual solar PV market scenarios 2024-2027 [127]

PV capacity increases in all three scenarios. The difference lies in the amount of the increase. In the low scenario, the expansion even decreases slightly at first. This is due to the fact that the market needs time to adjust to the new scale of solar expansion and to meet the demands of power systems. After that, however, expansion is expected to increase again. In the high scenario, the expansion of PV will increase as early as 2024. In medium scenario, expansion is also increasing. The medium scenario represents the average. Therefore, an increased expansion of PV can be expected on average.[127]

Mid to Long-term Forecast (2028-2050)

According to the DNV Energy Transition Outlook, the expansion of photovoltaics is set to more than triple by 2050. In addition, the levelized cost of solar energy will fall by a quarter by 2050. The levelized cost of electricity (LCOE) is a unit of measurement that expresses the costs for the construction and annual operation of a plant in relation to the amount of electricity generated over the entire service life of the plant. The levelized cost for solar PV in the world dip to approximately 21 USD/MWh = 0.1931 €/kWh by 2050. The levelized costs can be regarded as a feed-in tariff in so far as they are the minimum amount for the investment to be profitable. Based on these two forecasts, it is to be expected that the feed-in tariff will continue to fall.[108]

The forecast of the expansion and the forecast of the levelized cost of solar energy are shown in Figure 12.[108]

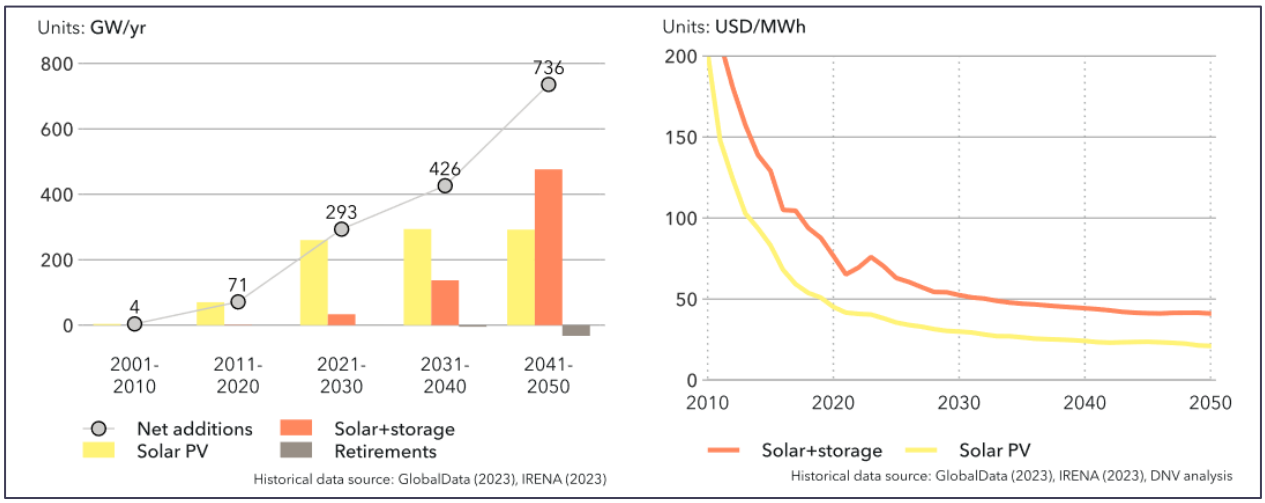


Figure 12: Global solar capacity additions and retirements and world levelized costs of solar energy [108]

A forecast of the change in the feed-in tariff in different European countries can be seen in Figure 13.

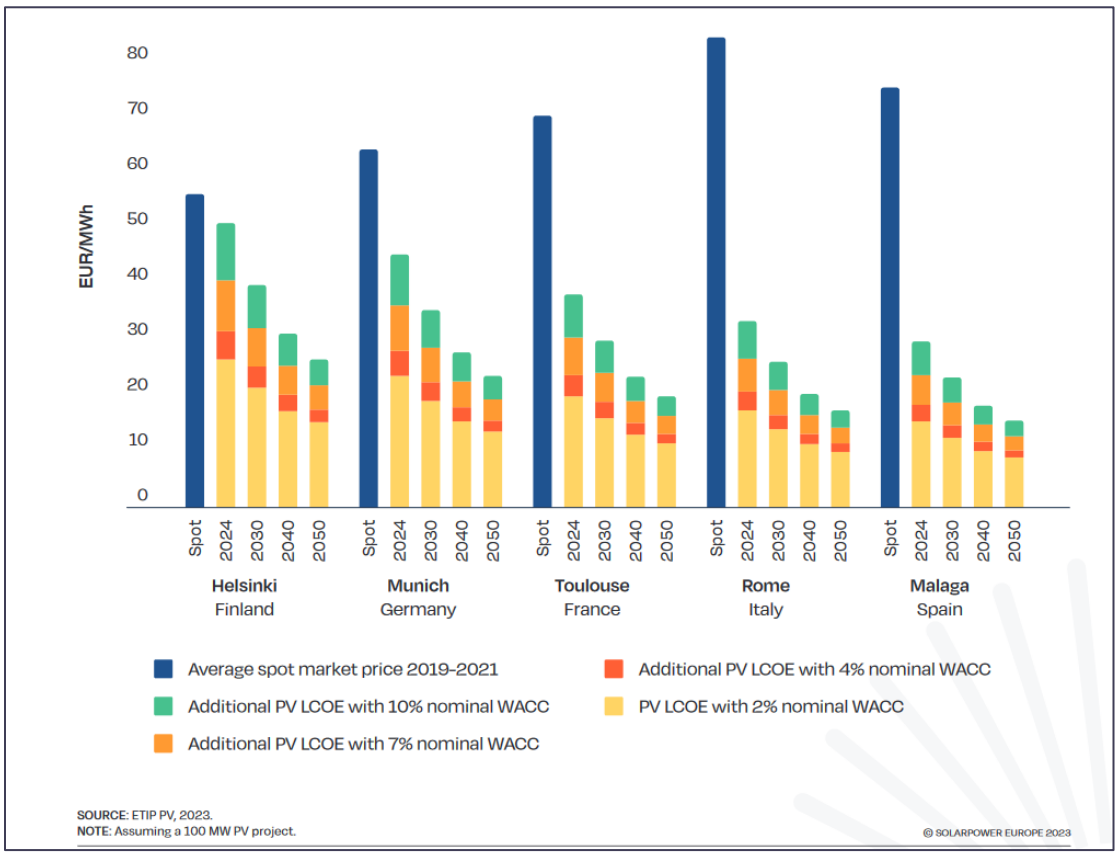


Figure 13: Utility- scale PV levelized cost of electricity (LCOE) under different EU locations and investment conditions (WACC) [127]

The forecast was created by the EU Market Outlook for Solar Power. The feed-in tariff decreases constantly over the years. It can be seen that the feed-in tariff will fall by at least half in several European regions. The feed-in tariff will then be around 0.020 €/kWh on average.[127] It is assumed that the feed-in tariff will change similarly throughout the EU.

Regional Differences

The expansion of PV systems has progressed differently in the various EU countries. The current status has an influence on future expansion. Countries with an already high proportion of PV systems will build comparatively fewer new systems in the next few years than countries where fewer PV systems have been installed to date.

Price Volatility

Price fluctuations will continue to exist and will probably increase further. The exact expansion of PV systems cannot be accurately predicted. It depends on many interrelated factors, such as personnel and availability. In 2023, these factors were already causing fluctuations in the expansion of PV and therefore also in the feed-in tariff. These fluctuations may of course also occur in the future.

5.2.4. Baseline for CBA-indicator 'CO_2 price'

Overview

Table 13 shows the CO_2 price in €/kgCO_2 in the participating countries in the Smart2B project.

Table 13: CO_2 price in €/kgCO_2 for different countries

	EU	Spain	Portugal	Sweden	Denmark	Austria	Italy	Greece	Germany	Belgium
CO_2 price in €/kgCO_2	0.045	0.015	0.024	0.117	0.262	0.045	0.057	0.057	0.045	0.057
Year	2024	2024	2024	2024	2024	2024	2024	2024	2024	2024
Reference	[128]	[128]	[128]	[128]	[128]	[128]	[128]	[128]	[128]	[128]

Most of the countries listed have different CO_2 prices. The governments of the countries themselves decide on the level of the price and refer to their own environmental targets.[128]

Some countries do not sets their own CO_2 prices. EU directives apply in these countries. This involves the emission trading system. An upper limit is set for the emissions caused in the EU and companies then have to buy certificates. The certificates then determine the emissions that may be released. In Italy, Greece and Belgium, these are the CO_2 prices.[128]

5.2.5. Projection for CBA-indicator 'CO_2 price'

Based on current forecasts, the CO_2 price in the EU show varying trends up to 2050, influenced by the transition to renewable energy, regulatory changes, and market dynamics.

Forecast (2023-2050)

The CO_2 price depends on the development of CO_2 emissions. There are many different long-term forecasts. In the various projections, CO_2 emissions are constantly approaching zero. The exact timing varies in the different forecasts.

This reduction of CO_2 emissions is to be achieved by pricing the emitted CO_2. This is the CO_2 price. The aim is to create a financial incentive to reduce CO_2 emissions. The CO_2 price therefore rises with decreasing CO_2 emissions. The course is similarly predicted. If the CO_2 price rises constantly, CO_2 emissions should also fall constantly.[108]

According to DNV Energy Transition Outlook, CO_2 emissions will have roughly halved by 2050. In this forecast, CO_2 emissions should be close to zero by 2100. CO_2 emissions are expected to fall steadily by several giga tons per year from 2030 to 2100. The reduction in CO_2 emissions is to be achieved by an increase in the CO_2 price The following is a forecast up to 2050, which makes it easier to compare the forecast with other forecasts. The change in CO_2 emissions up to 2050 is shown in Figure 14.[108]

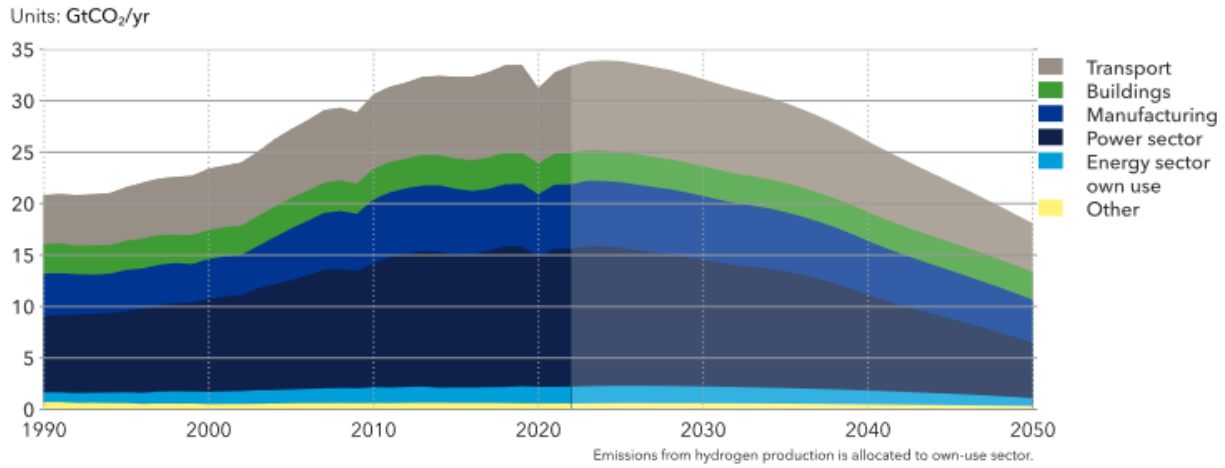


Figure 14: World energy- related CO_2 emissions by sector [108]

The forecast of the CO_2 price change is shown in Figure 15. According to this forecast, the CO_2 price for Europe will rise from 10 to nearly 250 USD/tCO_2. Converted, that is 229.95 €/tCO_2 and 0.230 €/kgCO_2 at an exchange rate of 1 USD = 0.92 €.[103]

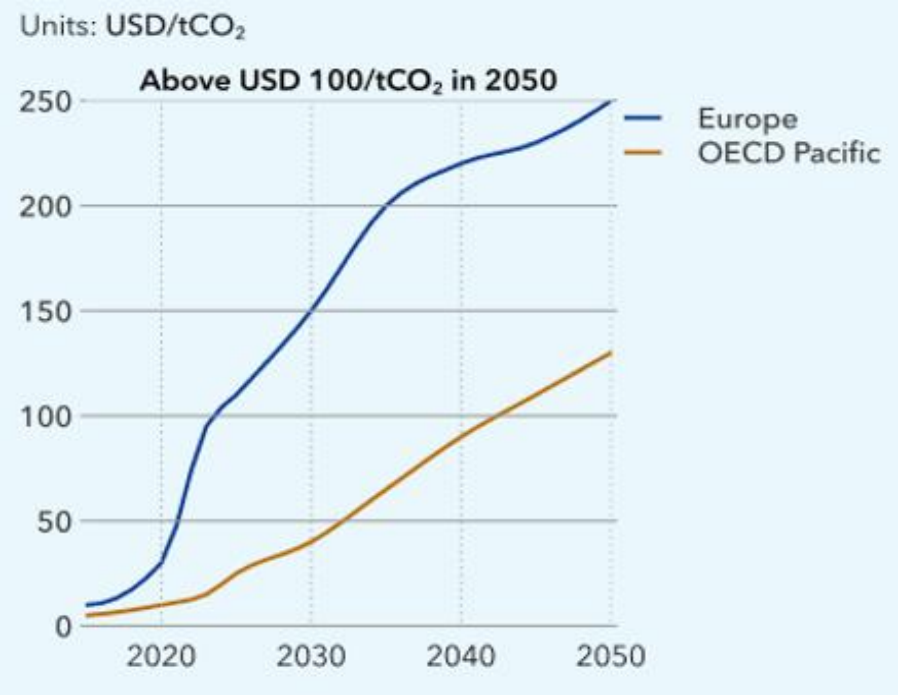


Figure 15: CO_2 price by region 2010-2050 [108]

According to the Net Zero by 2050 outlook, CO_2 emissions will be zero in 2050. By 2050, CO_2 emissions are expected to fall steadily. The forecast of CO_2 emissions is shown in **Figure 16**.[129]

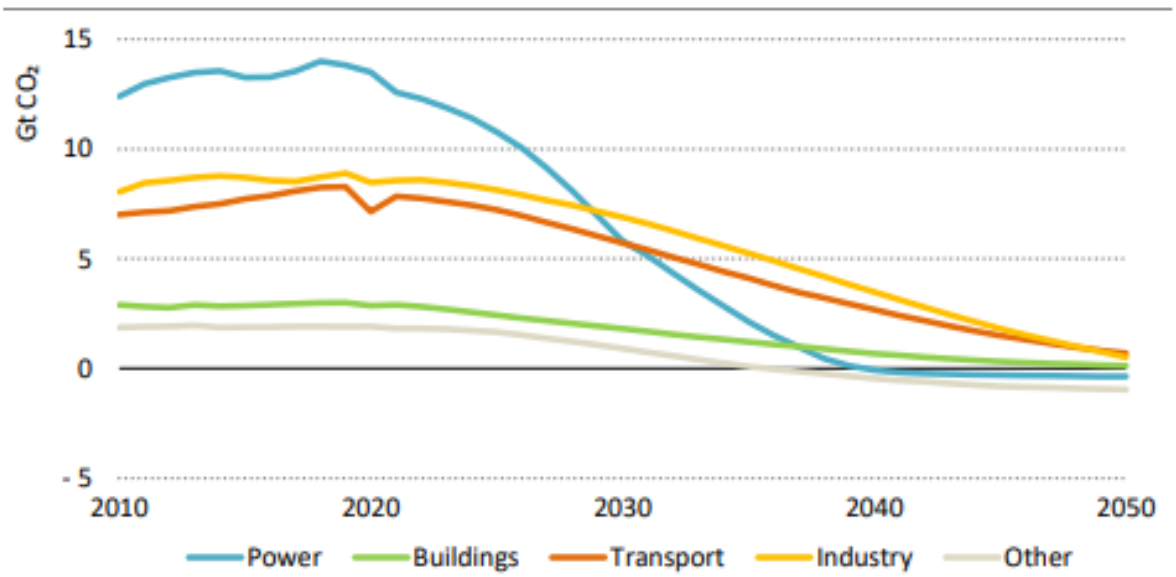


Figure 16: CO_2 emissions by sector in the net zero emission scenario [129]

As in the other forecast, CO_2 emissions are expected to fall due to rising CO_2 prices. The forecast of CO_2 prices up to 2050 is shown in **Table 14**. The net zero by 2050 outlook differs between three scenarios: the Stated Policies Scenario, the Announced Pledges Scenario (APS) and the Net Zero Emission by 2050 scenario. The Stated Policies Scenario (STEPS) provides an outlook based on the latest policy settings, including energy, climate, and related industrial policies. The Announced Pledges Scenario (APS) assumes all national energy and climate targets made by governments are met in full and on time. The Net Zero Emission by 2050 scenario assumes that no more CO2 emissions are emitted in 2050.[129]

Table 14: The forecast of CO_2 prices in USD/tCO_2 in the EU up to 2050 for the different scenarios [129]

Scenario	CO_2 prices in USD/tCO_2		
	2030	2040	2050
Stated Policies Scenario	120	129	135
Announced Pledges Scenario	135	175	200
Net Zero Emissions by 2050 Scenario	140	205	250

In both the World Energy Outlook and the Net Zero Emission Scenario, the forecast costs amount to 250 USD/tCO_2. Converted, that is 229.95 €/tCO_2 and 0.230 €/$kgCO_2$ at an exchange rate of 1 USD = 0.92 €. The costs are lower for the other scenarios by the Net Zero Emission outlook. It can therefore be assumed that 0.230 €/$kgCO_2$ will be the approximate upper limit of CO_2 costs in 2050.

Price Volatility

The CO_2 price is linked to CO_2 emissions. The CO_2 price is intended as a financial incentive to reduce one's own CO_2 emissions. It is intended to encourage people to reduce their own CO_2 emissions. The aim is to emit no CO_2 emissions The price therefore also depends on people's behaviour and is therefore difficult to predict. The CO_2 price is also determined by the individual countries and therefore also fluctuates within the EU. In the following, we therefore look at the average values for the EU as a whole.

5.2.6. Baseline for CBA-indicator 'flexibility market (DSO) participation'

A market analyses of available solutions in terms of flexibility services also besides the direct participation in Distribution System Operator (DSO) markets is done in chapter 3.

The DSO market plays a crucial role in the modern electrical grid by managing the distribution network and facilitating market mechanisms that integrate distributed energy resources (DERs), such as renewable energy sources, energy storage, and demand response systems.

DSOs are responsible for coordinating and aggregating the participation of various DERs in both retail and wholesale markets. This includes managing energy and regulation offers from DER aggregators, which can include demand response, energy storage, electric vehicle charging stations, and renewable energy aggregators. DSOs procure flexibility services from DERs to maintain grid stability, manage congestion, and ensure efficient operation. Flexibility markets enable DSOs to acquire these services to balance supply and demand at the distribution level.

For the baseline value for the participation in the DSO market, we refer to the results of Task 7.4. The team in task 7.4 analysed the revenues of participants in the existing DSO markets in Norway, Sweden, the United Kingdom, the Netherlands, Portugal, Belgium, and Italy resulted in a current baseline value of 392.60 €/MWh.

5.2.7. Projection for CBA-indicator 'flexibility market (DSO) participation'

Many EU countries have increased their renewable energy targets for 2030 in recent years. The need for flexibility will continue to grow across Europe with the increase in variable renewable energy generation. The increasing installation of flexible equipment in homes, such as electric vehicles, batteries and heat pumps, highlights the growing base for which this flexibility can be used.[130]

The World Energy Outlook highlights the rising importance of flexibility until 2050 as renewable energy accounts for a larger share of the energy mix. Technologies such as battery storage, smart grids, and demand-response will be key components to ensure supply security. Households will increasingly be recognized as important players in the flexibility market, and corresponding compensation models will be developed. These models might include dynamic pricing incentives, where households are compensated in real-time for adjusting their electricity consumption.[103]

In the DNV Energy Transition Outlook, it is also expected that the flexibility market will grow significantly, driven by the increased adoption of renewable energy and the need to maintain grid stability. Households providing flexibility by feeding electricity back into the grid or

adjusting their demand will increasingly be compensated. The use of demand-response programs, where households are financially rewarded for reducing or shifting their electricity consumption during peak times, is anticipated to increase. Compensation for households offering flexibility is expected to rise to incentivize participation in the flexibility market in accordance with the World Energy Outlook.[108]

Although several reports address the topic of flexibility market projection, none states specific values of even potential ranges of the revenues increase. That is the reason why a projection for the development of the flexibility market participants revenue is not possible at the moment.

We recommend considering only a stable inflationary increase in current values to be on the safe side. The development of the inflation rate is dealt with in chapter 5.3.3. In reference to the assumptions there and on the basis of a stable increase of the inflation rate of 1.8 % the revenue would increase until 2050 to 392.60 €/MWh x 1.018^{27} = 635.53 €/MWh = 0.6355 €/kWh

5.3. Conventional building renovation CBA-indicators baseline and projections

The following section deals with the analysis of the current conventional building renovation situation and suitable projections of the cost development in future.

We distinguish between 3 regions to consider the different building stock and renovation packages, as well as the different costs to be recognised in the European Union. For each region, one country has been chosen as a reference. Denmark represents Northern Europe; Italy represents Southern Europe and Germany represents Western Europe.

5.3.1. Definition of shallow and deep renovation of the building shell

Furthermore, a distinction is made between different renovation measures, called modernization packages. We refer to the modernization packages defined in the TABULA and EPISCOPE projects with modernization package 1 as shallow renovation and modernization package 2 as deep renovation. The exact requirements of these modernization packages depend on the country-specific regulatory and building typologies. The modernization packages are always compared with a reference case of the building typology under review. The definitions in TABULA/EPISCOPE for shallow and deep renovation in the respective countries are shown in Table 15.

Table 15: Definition of shallow and deep renovation for Northern, Western and Southern Europe

Area	Representative country	Shallow renovation	Deep renovation
Northern Europe **[131]**	Denmark	Standard renovation following the recommendations given by the Danish knowledge centre for energy savings in buildings	Ambitious renovation following the recommendations given by the Danish knowledge centre for energy savings in buildings
Southern Europe **[132]**	Italy	Standard refurbishment, considering the application of measures commonly used in the country	Advanced refurbishment, considering the realisation of measures that reflect the best available technology
Western Europe **[133]**	Germany	Complies with current standards and broadly meets the requirements of the Gebäude- Energie-Gesetz GEG (German Energy Performance of Buildings Act)	Significantly improved thermal insulation

Each country has specifications for the shallow and deep renovation of the building envelope consisting of measures towards the floor, walls, windows, and roof (see Table 16).

Table 16: Shallow and deep renovation measures for floor, walls, windows, and roof

Region	Representative country	Building component	Shallow renovation	Deep renovation
Northern Europe **[131]**	Denmark	Floor	• >10 cm insulation material	• >200mm insulation material
		Walls	• >10 cm insulation material	• >200mm insulation material
		Windows	• With double energy glazing	• With triple energy glazing
		Roof	• 300 mm insulation material	• 400mm insulation material
Southern Europe **[132]**	Italy	Floor	• From 7 to 12 cm thermal insulation material applied	• From 11 to 16 cm thermal insulation material applied
		Walls	• From 6 to 11 cm thermal insulation material applied	• From 10 to 15 cm thermal insulation material applied
		Windows	• -	• -
		Roof	• From 7 to 12 cm thermal insulation material applied	• From 11 to 16 cm thermal insulation material applied
Western Europe **[133]**	Germany	Floor	• Insulation in the rafter cavity 12 cm in total	• Insulation in the rafter cavity 30 cm in total
		Walls	• External thermal insulation composite system with 12 cm insulation	• External thermal insulation composite system with 24cm insulation
		Windows	• Windows with 2-pane thermal insulation glazing	• Windows with 3-pane thermal insulation glazing and insulated frames
		Roof	• Insulation 8 cm under the ceiling	• Insulation 12 cm under the ceiling

5.3.2. Baseline: Costs of shallow and deep renovation of the building shell

The renovation costs are calculated as follows. Firstly, the renovation costs are determined for each region. Therefore, we take cost approaches for the representative countries of past years. To be able to make projections of these costs for the current and future years, the renovation costs are adjusted using the annual Construction Cost Index for residential buildings (CCI_{res}) provided by Eurostat with normalisation to 100 for the year 2021.[134] For the Danish value in 2011 we additionally used Statistic Denmark as source.[135] In this way, the renovation costs can be estimated for all desired years. Table 6 shows the CCI_{res} values used for the conversion.

Table 17: Construction cost index for the different areas in different years [134] [135]

Region	Representative Country	CCI_{res} of cost approach (year)	CCI_{res} 2021	CCI_{res} 2023
EU-27	-		100	119.9
Northern Europe	Denmark	84.0 (2011)	100	114.9
Southern Europe	Italy	96.6 (2015)	100	110.8
Western Europe	Germany	78.8 (2015)	100	126.2

Northern Europe

The Danish Institute for Building Research wanted to obtain an economic overview of the possibilities of long-term financed energy-efficient refurbishment of single-family homes in Denmark. To this end, the costs of certain renovation measures were determined on the basis of several typical single-family houses.[136]

Only the costs for shallow renovation were determined. The deep renovation costs were determined on the basis of a publication by the department of civil engineering at the university of Denmark. In their publication, they estimate approximately 5 % more costs if the insulation is applied thicker in the renovation. These additional costs were taken into account for the deep renovation costs.[137] The costs und projection equation are shown in **Table 18**.

Table 18: Renovation costs of the building shell in Denmark in 2011 [136] [137] [134] [135]

Building shell component	Shallow renovation costs in Denmark 2011	Deep renovation costs in Denmark 2011	Renovation cost projection with CCI_{res} of specific year
Floor	94.1 €/m²	98.1 €/m²	$Cost_{2011}$ x CCI_{res}/84.0
Outer walls – cavity insulation	16.8 €/m²	17.8 €/m²	
Outer walls – external insulation	134.4 €/m²	141.12 €/m²	
Windows	293.4 €/m²	293.4 €/m²	
Roof	80.6 €/m²	107,44 €/m²	

Southern Europe

In project "Cost-Effective Energy and Carbon Emissions Optimization in Building Renovation", the IEA-EBC (International Energy Agency – Energy in Buildings and Communities Programme) pursued the goal of developing a new methodology that can serve as a basis for cost-effective renovation in Italy. The renovation costs for shallow and deep renovation were determined for 2015. Several detached houses were chosen as a reference. The costs und projection equation are shown in **Table 19**.[138]

Table 19: Renovation costs of the building shell in Italy in 2015 [134] [138]

Building shell component	Shallow renovation costs in Italy 2015	Deep renovation costs in Italy 2015	Renovation cost projection with CCI_{res} of specific year
Floor	30.5 €/m^2_{floor}	31.5 €/m^2_{floor}	
Walls	120.5 €/m^2_{walls}	124.5 €/m^2_{walls}	$Cost_{2015}$ x CCI_{res}/96.6
Windows	296 €/m^2_{window}	302 €/m^2_{window}	
Roof	77 €/m^2_{roof}	81.5 €/m^2_{roof}	

Western Europe

In 2015, the Institut Wohnen und Umwelt (IWU, engl.: Institute housing and environment) presented the renovation costs for buildings in Germany as cost functions. These functions were developed for typical renovation measures and are shown in Table 20. The costs are based on an example house. This is a detached house from the 1960s. For the renovation measures themselves, it is irrelevant on what basis they are applied. The costs can therefore be generalized for various detached houses.[139]

Table 20: Average renovation cost functions for the floor, walls, windows, and roof in Germany [139]

Building shell component	Cost functions for Germany in 2015
Floor	31.32 €/m^2_{floor} + 1.47 €/cm $_{insulating\ material}$ / m^2_{floor}
Wall	34.58 €/m^2_{wall} + 2.095 €/cm $_{insulating\ material}$ / m^2_{wall}
Window	152.07 x $A_{single\ window}^{-(0.2335)}$ €/$m^2_{window\ area}$
Roof	65.25 €/m^2_{roof} + 2.50 €/cm $_{insulating\ material}$ / m^2_{roof}

These cost functions are now adjusted for the respective shallow and deep renovation measure packages. Introduced in Table 16. Table 21 shows the renovation costs for shallow and deep renovation and the projection equation.

Table 21: Shallow and deep renovation costs of the building shell in Germany in 2015 [134] [139]

Building shell component	Shallow renovation costs in Germany in 2015	Deep renovation costs in Germany in 2015	Renovation cost projection with CCI_{res} of specific year
Floor	48.96 €/m^2_{floor}	75.42 €/m^2_{floor}	$Cost_{2015}$ x CCI_{res}/78.8
Wall	59.72 €/m^2_{wall}	84.86 €/m^2_{wall}	
Window	152.07 x $A_{single\ window}^{-(0.2335)}$ €/$m^2_{wind.\ area}$	152.07x $A_{single\ window}^{-(0.2335)}$ €/$m^2_{wind.\ area}$	
Roof	85.25 €/m^2_{roof}	95.25 €/m^2_{roof}	

For a better overview, Table 22 summarizes the introduced cost approaches for conventional building renovation costs in the different regions adjusted for the year 2023 with the CCIres for EU-27.

Table 22: Summarized conventional building renovation costs with CCIres for EU-27 in year 2023

Summarized conventional building renovation costs with CCIres for EU-27 in year 2023			
Region	**Building element**	**Shallow renovation**	**Deep renovation**
Northern Europe (Denmark)	Floor	134.32 €/m^2_{floor}	140.03 €/m^2_{floor}
	Outer walls – cavity insulation	23.98 €/m^2_{walls}	25.41 €/m^2_{walls}
	Outer walls – external insulation	191.84 €/m^2_{walls}	201.43 €/m^2_{walls}
	Windows	418.79 €/m^2_{window}	418.79 €/m^2_{window}
	Roof	115.05 €/m^2	153.36 €/m^2
Southern Europe (Italy)	Floor	37.86 €/m^2_{floor}	39.10 €/m^2_{floor}
	Walls	149.56 €/m^2_{walls}	154.53 €/m^2_{walls}
	Windows	367.40 €/m^2_{window}	374.84 €/m^2_{window}
	Roof	95.57 €/m^2_{roof}	101.16 €/m^2_{roof}
Western Europe (Germany)	Floor	74.50 €/m^2_{floor}	114.76 €/m^2_{floor}
	Wall	90.87 €/m^2_{wall}	129.12 €/m^2_{wall}
	Window	238.99 x $A_{single\ window}^{-(0.2335)}$ €/$m^2_{wind.\ area}$	231.39 x $A_{single\ window}^{-(0.2335)}$ €/$m^2_{wind.\ area}$
	Roof	129.71 €/m^2_{roof}	144.93 €/m^2_{roof}

5.3.3. Projections of the costs up to 2050

The following section deals with suitable projections of the cost development in the future. There is a strong relationship between rising construction costs and the inflation rate within the European Union (EU), which is intricate and characterized by mutual reinforcement. Analysing the various factors reveals several direct and indirect pathways through which these dynamics interact.

Construction costs significantly contribute to the overall inflation rate by influencing the Harmonized Index of Consumer Price (HICP), particularly through housing and maintenance costs. As construction costs increase, this leads to higher rental prices and housing expenses, which are critical components of the HICP.

Conversely, high inflation exacerbates construction costs through several mechanisms. Inflation drives up the prices of raw materials essential for construction, such as steel, concrete, and timber, due to increased production and transportation costs linked to higher energy prices and labour costs. Furthermore, inflationary pressures elevate import costs for construction materials. High inflation often prompts central banks to raise interest rates to curb inflationary pressures. These higher interest rates increase the cost of financing construction projects, thereby raising the overall costs associated with new builds and

renovations. Additionally, inflation leads to higher wages in the construction sector as workers demand compensation for their reduced purchasing power. These increased labour costs further contribute to the rising construction costs. A projection of the inflation rate was prepared by Statista up to 2028 (see Figure 17).[140]

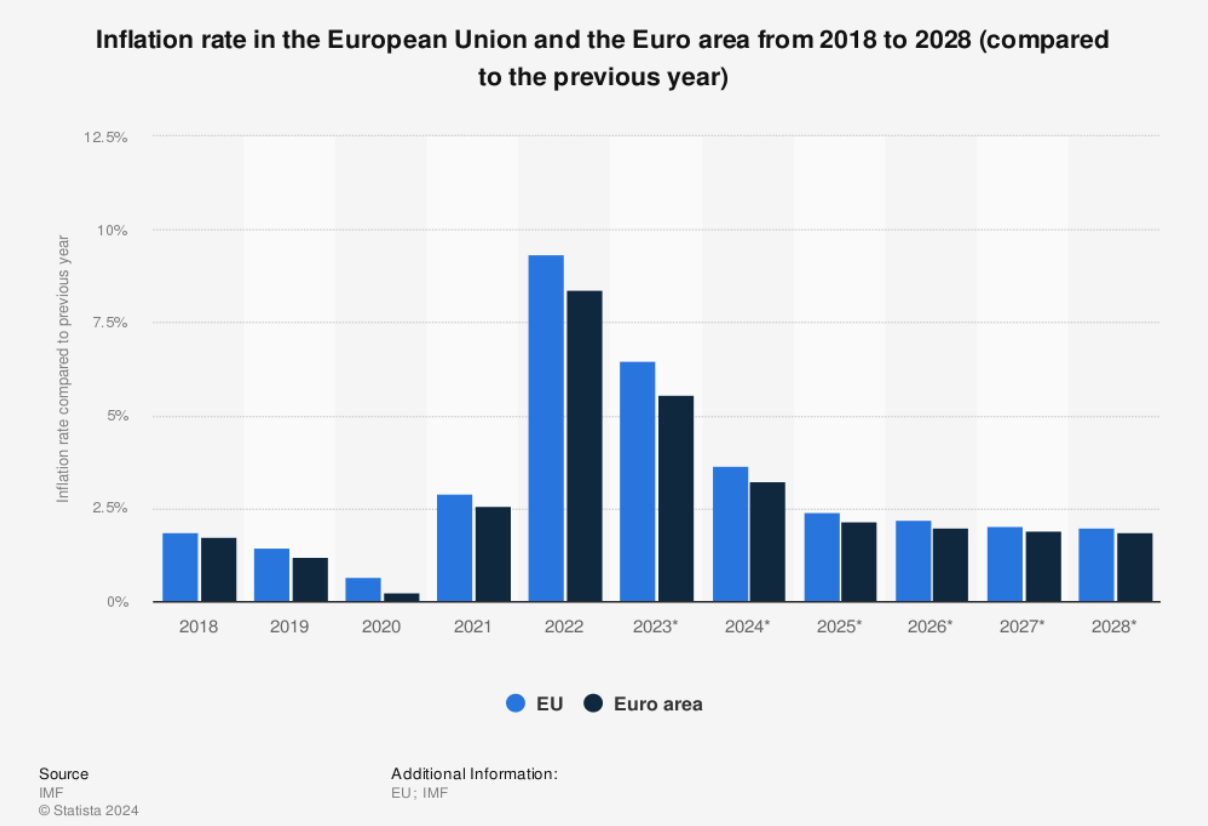


Figure 17: Inflation rate in the European Union and the Euro area from 2018 to 2028 [140]

Table 23 compares the inflation rate and the construction cost index for residential building (CCI_{res}) of the EU for three different scenarios. The first scenario covers the predominantly stable period from 2015 to 2021. Even though the Covid-19 pandemic did have an impact on the economic system, the inflation rate was not affected by it to a great extent. The second scenario shows the years 2024-2028, which should in accordance with the forecast shown in Figure 17 also be a stable period without a further crisis. The average value of both stable periods will be used as the representative value for a generally stable period. The years 2022 to 2024 are shown as the third scenario. These years were influenced by the Russia-Ukraine conflict. This period is representative of a period with an economic crisis.

Table 23: Comparison of Inflation Rate and CCI_{res} increase in EU-27 [134]

Average Values	Stable period 1 2015-2017	Stable period 2 2018-2021	Crisis period 2022-2023	Stable period 3 2024-2028	Stable periods 1-3 (weighted)
Inflation rate in %	0.6	1.7	7.8	2.5	1.8

CCI_{res} increase in %	1.3	3.6	9.6		*3.7*
ΔCCI_{res}/Infl.-r.	2.0	2.1	1.2		*2.05*

The development of the inflation rate and the CCI_{res} are now estimated up to the year 2050. A distinction is made between the case of stable development and development with one additional temporal crisis, like the one in the year 2022 and 2023 due to the Russia-Ukraine conflict. The inflation rate is the total percentage increase of the Harmonised Index of Consumer Prices (HICP). The calculated values are shown in **Table 24**.

Table 24:Projection of HICP and CCI_{res} for EU-27 based on average increase values from previous years

	2023	2050 – stable scenario Approximation for stable development	2050 – crisis scenario Approximation for development with temporal crisis
HICP EU-27	126.4	$126.4 \times 1.018^{27} = 204.6$	$126.4 \times 1.078^{2} \times 1.018^{25} = 229.4$
CCI_{res} EU-27	119.9	$119.9 \times 1.037^{27} = 319.8$	$119.9 \times 1.096^{2} \times 1.037^{25} = 357.2$

5.3.4. Energy savings with shallow and deep renovation

In the following, we will focus on the energy savings that can be achieved through the renovation measures. The energy saving is given as a percentage of the previous demand.

Northern Europe

Table 25 shows the effects of the shallow renovation in Denmark as representative for Northern Europe. These are averaged energy savings for several residential building types [131].

Table 25: Energy savings of shallow and deep renovation of the building shell of an average Danish building in % compared to the previous demand [131]

Area	Country	Energy savings with shallow renovation of the building shell	Energy savings with deep renovation of the building shell
Northern Europe	Denmark	46 %	50 %

Southern Europe

Table 26 shows the effects of the shallow and deep renovation in Italy as representative for Southern Europe. These are averaged energy savings from several single-family houses.[141]

Table 26: Energy savings of shallow and deep renovation of the building shell of an Italian building in % compared to the previous demand [141]

Area	Country	Energy savings with shallow renovation of the building shell	Energy savings with deep renovation of the building shell
Southern Europe	Italy	41 %	69 %

Western Europe

Table 27 and **Error! Reference source not found.** show the effects of the deep and shallow renovation in Germany. The energy demand of the building was reduced by 28 % from 180 to 129 kWh/m²a with the shallow renovation of measures. With the deep renovation of measures, a reduction of 69 % from 180 to 57 kWh/m²a was achieved. The energy savings are based on an example building from the 1960s. This is the same building that was used for the renovation costs.[133]

Table 27: Energy savings of shallow and deep renovation of the building shell of a German building in % compared to the previous demand [133]

Area	Country	Energy savings with shallow renovation of the building shell	Energy savings with deep renovation of the building shell
Western Europe	Germany	28 %	69 %

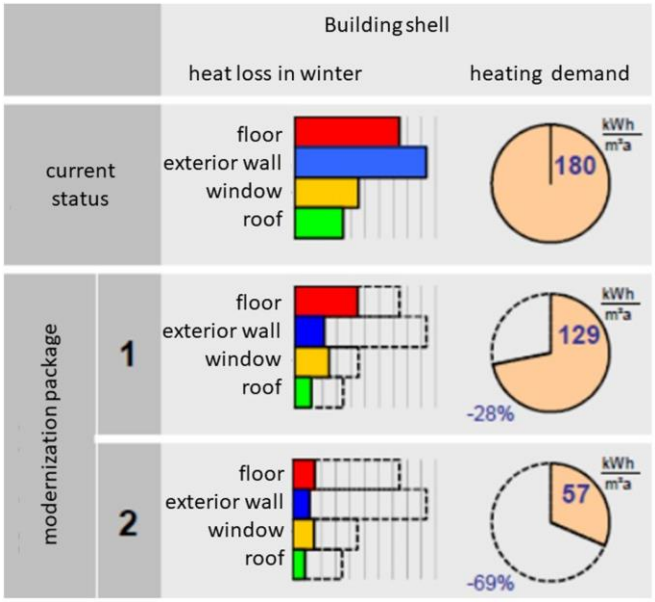


Figure 18: Energy savings of shallow and deep renovation of the building shell of a German example building in % compared to the previous demand in the reference situation [132]

The relative savings, resulting from the renovation measures on the outer shell can be translated into monetary savings via the energy costs of the specific energy mix for the heat supply. It should be noted that the energy mix and the costs to be applied for this must be

determined individually for the building under consideration. In future Renewable Energy Sources as well as the electrification of the heat supply will have an influence on these costs (see chapter 5.2.1)

5.4. Combination of CBA-indicator projections to develop market scenarios

Table 28 gives and overview about the evaluated projection scenarios of the indicators in the energy market and for the projection of building renovation costs.

Table 28: CBA- indicator projections

CBA- indicator	Scenario	Projection for 2050
Electricity price	Stated policies scenario (STEPS)	0.5401 €/kWh
	Announced pledges scenario (APS)	0.5057 €/kWh
Feed- in tariff	Average scenario	0.020 €/kWh
CO_2 price	Stated policies scenario (STEPS)	135 €/kgCO_2
	Announced pledges scenario (APS)	200 €/kgCO_2
	Net zero emissions scenario	250 €/kgCO_2
Flexibility market (DSO) participation revenue	Baseline + inflation	0.6355 €/kWh
Projection index for conventional building renovation costs: CCI_{res}	Stable scenario	319.8
	Crisis scenario	357.2

Due to the high uncertainties associated with the flexibility and feed-in tariff indicators—stemming from a lack of data for projections up to 2050 and the relatively recent introduction of flexibility into legislation and policies—we opted not to base our scenarios solely on these indicators. Instead, we considered these factors more generally across all scenarios. Consequently, we proposed incorporating the projected values within the following combined market scenarios:

- Scenario A: STEPS Energy Market+ Stable Building renovation market
- Scenario B: STEPS Energy Market + Crisis Building renovation market
- Scenario C: APS Energy Market + Stable Building renovation market
- Scenario D: APS Energy Market + Crisis Building renovation market
- Scenario E: APS Electricity price + Net zero CO_2 price+ Stable Building renovation market

- Scenario F: APS for Electricity price + Net zero CO_2 price + Crisis Building renovation market

6. Conclusion

The Smart2B project focuses on enhancing the smartness level of various building types. This deliverable provided a detailed assessment of the smart technologies market, with a particular emphasis on recent trends, growth determinants, and the competitive landscape. It examines various segments within the smart home solutions domain, including HVAC control systems, smart thermostats, and advanced energy management technologies. The assessment evaluates how leading manufacturers are innovating and positioning their products to address the dynamic needs of both consumers and commercial entities. An in-depth overview of key manufacturers within the smart technologies sector was conducted, focusing on their flagship products, market strategies, and technological innovations. The discussion highlighted companies such as Bosch, BeeBryte, DABBEL, Homix, Johnson Controls, MeteoViva, R8 Technologies, and Shelly. Each manufacturer's unique selling propositions, market focus, technological advancements, and strategic initiatives aimed at enhancing energy efficiency, user comfort, and sustainability in both residential and commercial building applications were examined.

A comprehensive analysis was conducted on manufacturers and products within the smart energy sector. Competitors were categorized based on their value propositions, and products were evaluated across different categories. Relevant SWOT analyses were performed to identify existing trends and gaps in both the BEMS and energy flexibility markets. This analysis provides a detailed assessment of the smart technologies market, focusing on recent trends, growth determinants, and the competitive landscape. Strengths included highly advanced solutions across various application levels and markets and significant financial returns with low initial investments. Weaknesses involved challenges in holistic approaches and effectively communicating with customers to build trust in these new technologies. Opportunities were found in the growing demand for renewable energy integration and increasing electrification in heating and transport sectors. Threats included regulatory uncertainties and differences across markets, increasing customer expectations and the ensuring of cybersecurity.

The subtask of market SRI Assessment applied the SRI-methodology to evaluate the SRI across different EU member states. A detailed questionnaire covering nine technical domains of SRI calculation was designed to gather data from experts in the field of building automation and control systems on both residential and non-residential buildings in seven EU-countries. The resulting SRI scores reflect the readiness of buildings in different regions, providing crucial insights for market entry strategies. This data-driven approach ensures that the assessment is robust and offers a clear understanding of the current market conditions.

The exploitation goal was further improved by conducting market prognoses on key indicators to develop market scenarios which serve as verification of Smart2B's market penetration assumptions. Several market scenarios were developed using CBA indicators, considering factors such as electricity prices, CO_2 prices, feed-in tariffs, flexibility services, and energy savings from renovations. These scenarios aim to provide a robust foundation for strategic planning and market entry, projecting Smart2B's market penetration and evaluating the economic viability of the proposed solutions. By analysing competitors and market conditions, the deliverable thus offers a robust foundation for strategic planning and market entry, projecting Smart2B's market penetration and evaluating the economic viability of the proposed solutions.

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