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Drivers, Barriers, and Stakeholders' Requirements for BAUNs

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Drivers, Barriers, and Stakeholders' Requirements for BAUNs

Deliverable number	D1.1
Deliverable name	Drivers, Barriers, and Stakeholders' Requirements for BAUNs
Lead beneficiary	HAEE
Description	This deliverable is directly linked to the activities foreseen in Task 1.1, considering the identification of the different factors that enable or hinder the transformation of smart buildings into transactive/autonomous utility nodes of the multivector network. It comprises the first version of D1.2, that will focus on the identification of all stakeholders', relevant performance, security, data management, scalability, and replicability requirements at Pilot levels; through dedicated workshops and questionnaires deployment.
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Abbreviations

PS	Pilot Site
B2G	Building to grid
G2B	Grid to building
EU	European Union
EPBD	Directive on Energy Performance of Buildings
EED	Energy Efficiency Directive
DP	Data Protection Directive
BAUNS	Buildings as Active Utility Nodes
PESTEL	Political Economic Social Technological Environmental Legal
SRI	Smart Readiness Indicator
DSO	Distribution System Operator
TSO	Transmission System Operator
SC	Self-Consumption
CSC	Collective Self-Consumption
NZEB	Nearly Zero-Energy Buildings
NECP	National Energy and Climate Plan
DEEP	De-risking Energy Efficiency Platform
SFSB	Smart Finance for Smart Buildings
BACS	Building Automation and Control Systems
ICT	Information and Communication Technologies
BAS	Building Automation Systems
SBA	Smart Building Alliance
DR	Demand Response
GDPR	General Data Protection Regulation
ESG	Environmental Social Governance

EXECUTIVE SUMMARY

EVELIXIA project aims to demonstrate and assess the sustainability of B2G/G2B solutions and user acceptance in seven (7) pilot sites (PS) with exemplar buildings, which act as active utility nodes. The scope is to render the buildings energy efficient, to facilitate a two-way communication between the grid and the occupants, capitalizing on flexible technologies, to use analytics supported by sensors and controls, and to become flexible, reducing, shifting, or modulating energy use according to occupant needs, while considering utility signals.

Along the technical solutions that will be developed, EVELIXIA will create and validate sustainable business models for the market uptake of B2G and G2B services. To achieve that and enhance inclusiveness, the project will foster cooperation and knowledge sharing between different stakeholders (incl. social innovators).

Considering that WP1 includes the definition of technical, business, societal and legal requirements, PSs use-cases, evaluation and monitoring framework, and the EVELIXIA technical architecture integration roadmap, setting up a concrete foundation for the technical developments foreseen within WP2-WP5; the scope of this deliverable falls within this framing. The use of PESTEL methodology was used to identify the most important barriers to development of sustainable buildings by analysing the political, economic, social, technological, legal and environmental elements of the participating countries and at EU level.

The subject was, firstly, approached by a literature review and the formulation of a questionnaire to identify the status of these elements in the T1.1 participating partner countries. Following that, a participatory workshop was organised to complement the questionnaire. During group work, we defined the barriers and drivers, including the stakeholders involved in the B2G and G2B concept.

To sum up, D1.1 defines the factors that enable and hinder the integration of smart buildings into a smart city and examine them from not only the technology perspective but also include the social, environment, economic aspect.

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1 INTRODUCTION

1.1 Scope & Objectives

The scope of this deliverable is to make a first assessment of the drivers and barriers that promote or challenge, respectively, the transformation and implementation of smart buildings into active utility nodes within the frame of a smart city.

The target was to identify the Political (policies, regulations, tariffs), Economic (investment costs, depreciation, Inflation), Social (perceptions, acceptance, awareness), Technical (R&D, International cooperation), Legislative (industry regulations, IPR), and Environmental (Impact on environment, climatic conditions) factors that act as drivers or barriers at EU level and at country level.

It was also important to identify the stakeholders that play an important role in this transformation and define their requirements. This sets the base for the later activities of Task 1.1 and along with the other activities in WP1 i.e. definition of use cases (T1.2) and development of a stakeholder engagement strategy (T1.3) will provide valuable input for the organisation of a targeted participatory workshop (T7.4), which will lead to innovative business models for the specific use cases of the pilots.

1.2 Building Sector – EU Goals

In the European Union (EU), buildings are major energy consumers and contributors to carbon emissions, accounting for 40% of energy usage and 36% of CO₂ output. The significance of indoor environments cannot be overstated as Europeans spend around 90% of their time indoors, underscoring the vital link between indoor conditions and well-being [1].

However, a substantial challenge looms large: approximately 65% of the EU's buildings were constructed prior to 1980. This aging building stock poses a hurdle in achieving the ambitious goal of full decarbonization by 2050 [1]. The rate of building renovations stands at a mere 1% annually, a stark disparity against the urgent need for upgrades.

The transformative potential of buildings is immense. With the right upgrades, they can not only curb emissions but also play a pivotal role in shaping a more flexible energy system. This includes enabling energy production, storage, demand

response mechanisms, and facilitating infrastructure for electric vehicle charging. But these innovations hinge on a comprehensive revamp of the existing building infrastructure—an endeavour that requires systemic changes.

The Directive on Energy Performance of Buildings (EPBD - EU/2010/31) [2] serves as the cornerstone of this transformative journey. Initiated in 2002 and revised in 2010 and 2018 as part of the Clean Energy Package, the EPBD charts a clear path toward decarbonizing Europe's building stock by 2050. Not merely a set of aspirations, it equips EU Member States with the necessary tools and guidelines to navigate this challenging terrain.

Complementing the EPBD, the Clean Energy Package aims to bridge regulatory gaps and construct a robust framework essential for meeting the EU's commitments under the Paris Agreement. The emphasis is on bolstering the support structure necessary for the decarbonization of the building sector, aligning it with broader climate goals.

The European Green Deal amplifies these efforts, particularly through its announcement of a Renovation Wave targeting energy efficiency improvements in buildings. This wave doesn't just focus on cutting-edge upgrades but also emphasizes affordability for EU citizens. The ripple effects of this initiative extend beyond energy efficiency, promising reductions in energy bills, alleviating energy poverty, stimulating the construction sector, and generating local employment opportunities.

The imminent publication of the Renovation Wave's communication strategy, slated for September 2020, is poised to further galvanize these transformative endeavours as part of the European Green Deal's overarching goals.

The EU's two decades of experience in shaping building policies, coupled with the varied approaches of Member States in implementing these policies, offer a treasure trove of insights and innovations. These lessons learned are invaluable and possess the potential to inform policymaking not just within the EU but also in other G20 nations, regardless of their specific building stock, renovation rates, or local climatic conditions.

At the heart of these efforts lies the Energy Efficiency Directive (EED), which acts as the central legal framework guiding energy efficiency policies within the EU. Initially established in 2012 to achieve a 20% energy efficiency target by 2020, its 2018 revision has raised the bar by setting a more ambitious 32.5% energy efficiency

target for 2030. Notably, it also extends key provisions, ensuring a sustained commitment to enhancing energy efficiency well beyond 2020.

1.3 Buildings as Utility Nodes (BAUNs)

Buildings acting as utility nodes in the framework of a smart city refer to the integration of buildings with advanced technologies that enable them to function as part of a larger, interconnected system. These buildings can collect, analyse, and share data to optimise their energy consumption, resource management, and overall performance. By doing so, they contribute to the achievement of the European Union's goals on energy efficiency in buildings.

One of BAUNs' key attribute is that they are equipped with intelligent energy management systems, which integrate various sub-systems such as heating, ventilation, air conditioning (HVAC), lighting, and security. These systems monitor and control the energy consumption of the building in real-time allowing it, thus, to operate more efficiently, minimize energy waste and enabling proactive decision making [].

Smart Grid Integration and interaction with it allows smart buildings to exchange energy with the grid according to its needs enabling optimisation of the energy consumption by the building depending also on the available renewable resources. Inclusion of energy storage systems, such as batteries or thermal energy storage, allows buildings to store the generated excess energy and to be used during peak demand periods. This reduces the overall energy demand from the grid promoting energy efficiency.

Data Analytics and Artificial Intelligence (AI) play a significant role in BAUNs as they can analyse energy consumption patterns and predict future needs by collecting data through smart sensors and meters installed throughout the building. This information can be used to optimize energy usage and identify areas for improvement, leading to increased energy efficiency [].

Finally, buildings acting as utility nodes can encourage sustainable behaviour and occupant engagement. Smart buildings can encourage occupants to adopt energy-efficient practices through educational programs, real-time feedback on energy consumption and resource usage, and incentivising green behaviour. This promotes a culture of energy efficiency within the building and contributes to the EU's energy goals.

1.4 Stakeholders

In a smart city, smart buildings play a crucial role as utility nodes, integrating various technologies and systems to improve efficiency, sustainability, and overall quality of life for residents. The main stakeholders in smart buildings can be categorised into the following groups, each with their unique characteristics and responsibilities.

1.4.1 Building Owners/Developers

They are the initial investors and decision-makers in the development and management of smart buildings. They are responsible for ensuring the implementation of smart technologies, maintaining the building's infrastructure, and providing a comfortable and safe environment for occupants. They also need to focus on energy efficiency, cost optimisation, and maximising the return on investment.

1.4.2 Building Managers/Operators

They oversee the day-to-day operations and management of smart buildings by monitoring and controlling the building's systems, including HVAC, lighting, security, and other utilities. They need to ensure smooth operations, maintain the building's infrastructure, and address any issues that arise.

1.4.3 Service Providers

These are mainly companies that supply and maintain various smart technologies, such as energy management systems, security systems, and IoT devices. Their responsibility is to ensure the quality and operation of their products and services, provide technical support, and collaborate with other stakeholders to enhance the overall performance of the BAUNs.

1.4.4 Government Agencies/Regulatory Bodies

They are responsible for establishing policies, guidelines, and standards related to smart buildings and smart cities to facilitate the adoption of smart technologies, promote sustainability, and ensure the safety and well-being of residents. They also need to monitor the compliance of smart buildings with the established rules and guidelines.

1.4.5 Research Institutions/Academia

They contribute to the development of new technologies, methodologies, and best practices for smart buildings by conducting research, providing expertise, and collaborating with other stakeholders to improve the efficiency and performance of smart buildings.

1.4.6 Tenants/Occupants

Being the end-users of the smart building, living, or working within the premises they need to provide feedback for improvements, and contribute to energy conservation and sustainable practices.

1.4.7 DSO/TSO

DSOs play a vital role in ensuring the efficient management and distribution of resources in smart buildings acting as utility nodes. Their involvement helps optimise energy consumption, maintain grid stability, and promote sustainable practices within the building and the larger energy ecosystem.

TSOs do not have a direct role in smart buildings acting as utility nodes. However, their responsibilities in maintaining grid stability, ensuring grid integration, and managing emergencies can indirectly impact the energy management strategies of smart buildings. The collaboration between TSOs and DSOs can further enhance the efficiency and sustainability of energy management within these buildings.

1.4.8 Aggregators

The role of aggregators in such systems is to optimise energy consumption and distribution, facilitate demand response programs, promote renewable energy integration, offer financial incentives, enable energy trading, and contribute to grid stability. Their involvement helps smart buildings operate more efficiently, sustainably, and cost-effectively.

2 WORKING APPROACH

In order to identify specific drivers and barriers that pertain to the transformation of buildings into utility nodes (BAUNs), but also the relevant stakeholder groups and their respective requirements, we implemented a mixed-methods approach comprised from two separate but interconnected processes: (i.) the desk research and literature review process around the field of smart buildings and their integration into the grid, and (ii.) the extraction of external input from our consortium partners. This second process of external feedback was achieved using a questionnaire that was sent out to the partners and through the organisation of an online workshop. These two processes were chosen to cover both the EU-level and the national contexts of each of the pilot case countries, respectively. A visual overview of this endeavour is presented in Figure 1.

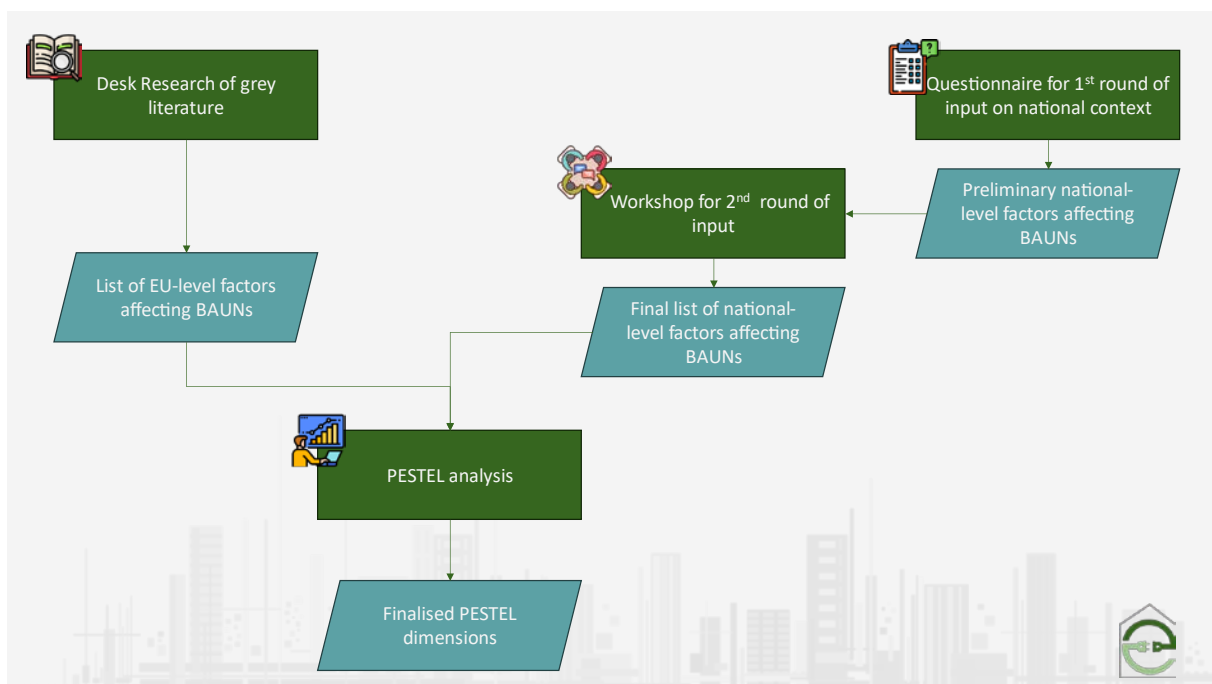


Figure 1. Visual overview of the working approach

As a first step, we set out to identify key trends and patterns that emerge around the central concept of BAUNs, and to analyse them through the PESTEL framework. This allowed us to develop an initial understanding of the different concepts surrounding the idea of BAUNs and come up with a set of relevant search keywords, e.g., {“buildings,” “smart buildings,” “B2G,” “smart grid,” “utility node”, “demand response”, “social aspects”, “PESTEL”, “regulations”, “technological

solutions”}. These keywords guided our desk research in scientific and grey literature.

More specifically, in the case of scientific literature, we conducted a search of energy-related peer-reviewed journal articles in the “Science Direct” and “Google Scholar” databases, using the above keywords. Search results were not constrained but the period covering more recent years was naturally preferred. In the case of grey literature, the search process was centred around relevant technical reports and position papers to supplement existing knowledge and experience. For this case, search results were also not constrained but more recent and updated material was preferred. Finally, we also made use of previous research knowledge found in deliverables from other relevant EC-funded projects.

In parallel, the questionnaire was developed to identify the national context of the countries participating in T1.1 regarding the PESTEL dimensions of our analysis on the transformation of buildings into BAUNs.

It also noteworthy to mention that in T1.1, the partners that participate in are not all of them involved in a PS. Likewise, not all PSs are represented in the Task. For this reason, it was decided in the first part of T1.1 to work at EU level and with the partners that participate in. The status of the pilots that are not represented (Danish & Greek) is summarised in the Section 5.1 based only on literature. During the second part of T1.1, and through a workshop that will be organised, a more to the point analysis will be conducted for all PSs.

Finally, the whole process of defining drivers and barriers was also aided by an online workshop with some of our internal partners, where they had the opportunity to provide insightful feedback on the overall structure of the framework and on what should be included and/ or emphasized regarding the produced list of drivers and barriers. The multitude of perspectives and variety of backgrounds of the consortium members enabled us to incorporate aspects, previously not thought of or disregarded, which in turn enriched the quality and content of the final results.

2.1 PESTEL

The working approach was based on the PESTEL framework, which is an acronym for *Political, Economic, Social, Technological, Environmental, and Legal* factors and is a powerful analytical tool employed in strategic planning to understand and

evaluate the external macro-environmental factors that can impact an organization, industry, or, in this case, the broader concept of adoption of Buildings as Utility Nodes (BAUNs). Developed as an extension of the traditional PEST analysis, PESTEL encompasses a broader spectrum of factors, providing a comprehensive lens through which to examine the complex interplay of influences on a subject.

- **Political Factors:** Political considerations play a pivotal role in shaping the landscape for BAUN adoption. Government policies, regulations, and political stability can either facilitate or impede the integration of BAUNs into the urban fabric. By scrutinizing the political climate, researchers can uncover incentives, subsidies, or barriers that may influence the widespread embrace of BAUNs.
- **Economic Factors:** The economic dimension encompasses factors such as inflation, exchange rates, and economic growth. Economic stability and the availability of financial resources impact the feasibility of BAUN implementation. Understanding economic factors provides insights into potential funding mechanisms, cost-effectiveness, and the overall economic viability of BAUN projects.
- **Social Factors:** Social dynamics are integral to the acceptance and success of BAUNs within communities. Public attitudes, cultural norms, and societal values can influence the degree of acceptance and integration of BAUNs. An in-depth exploration of social factors can potentially highlight public resistance, community engagement strategies, and the social impact of BAUNs.
- **Technological Factors:** The technological landscape forms a critical component of BAUN adoption. Advances, and more importantly access in smart building technologies, energy management systems, and connectivity solutions are instrumental in the effective functioning of BAUNs. By assessing technological factors, we can identify opportunities for innovation, potential technical challenges, and the overall readiness of the technological ecosystem.
- **Environmental Factors:** Given the emphasis on sustainability and environmental consciousness, BAUNs' success is correlated to their

environmental impact. Thus, factors such as energy efficiency, carbon footprint, and resource conservation need thorough evaluation.

- **Legal Factors:** The legal landscape within which BAUNs operate can significantly influence their implementation. Compliance with building codes, zoning regulations, and energy efficiency standards are critical considerations. Researchers must delve into legal factors to ascertain the legal constraints, permissions, and obligations associated with BAUN deployment.

Employing the PESTEL framework in the context of BAUNs involves a meticulous examination of each factor to uncover both drivers and barriers for adoption. By analysing the concept of BAUNs through the lens of the PESTEL dimensions, we can gain a nuanced understanding of the multifaceted forces shaping the fate of BAUNs.

2.2 Empirical Tools

In addition to that, empirical methods were also chosen for the purposes of gathering expert opinions on the matters of the uptake of BAUNs. Specifically, a two-step process was employed, combining a questionnaire with open-ended questions and an online workshop both addressed to the consortium partners, with the aim of extracting their expert opinion regarding their countries' national context when it comes to the landscape of smart buildings and BAUNs.

2.2.1 Questionnaire

The questionnaire was developed as part of the initial stages of the research. As it was important to gather detailed and nuanced information about the national context of the participating countries, the questions were chosen to be open-ended and were also formulated to address the specific dimensions of the PESTEL framework, meaning that for each dimension of the PESTEL framework 2-3 questions were created. The questionnaire is presented below in Table 1.

Table 1. Questionnaire developed for the extraction of experts' opinion on BAUNs.

POLITICAL	Has the EU legislation regarding Smart Buildings or BAUNs been transferred into national law?
	Are there any specific policy schemes supporting the uptake of Smart Buildings or BAUNs in your country? If so, please describe them briefly.
	How has the national policy framework impacted your pilot case (positively or negatively)?
ECONOMICAL	What factors determine the economic feasibility of BAUNs to generate revenue? How these factors have affected so far, your pilot case?
	Are there economic incentives and support measures provided in your country for the development and uptake of Smart Buildings or BAUNs? If so, please describe them briefly.
	Are there any financial benefits in your pilot case? If so, how are the potential financial benefits distributed among the occupants?
	Were there any hidden/unexpected costs that occurred during the development of your pilot case?
SOCIAL	To the best of your knowledge, what is the current state of public awareness and consequently the public acceptance of the smartification of buildings?
	Are there concerns expressed by the public in relation to Smart Buildings or BAUNs, e.g. data privacy and security issues, energy consumption increase, ease of use, etc.?
	How do the social interactions and relationships of their residents influence the implementation of Smart Buildings or BAUNs? What is the decision-making process implemented in your pilot case?
TECHNOLOGICAL	What type of smartification technology have you used in your pilot case, e.g. smart meters, local energy production, etc.?
	Are there easily available technological solutions in the market for the smartification of buildings?
	What is your experience with the technology you are using in your pilot case? Has it been easy-to-use, or has it been a hindrance?
	How prepared is the grid infrastructure in your city/area to accommodate the connection of a smart building or BAUN, and what steps need to be taken to ensure a seamless integration?
ENVIRONMENTAL	How has the local environment and climate has affected the development of smart buildings in your pilot case?
	How do existing environmental regulations impact the development and implementation of smart buildings in your country?
	What are the key environmental standards or certifications that smart buildings must adhere to, and how do they influence their design and operation?
	Is/Was an environmental impact assessment study required in your pilot case and which dimensions do you examine?

LEGAL	Are smart buildings and other relating concepts like prosumers, energy communities, etc. formally recognized in your national legislation?
	What legal frameworks or regulations exist and how are data privacy laws impacting the collection, storage, and usage of data within smart buildings?
	How do existing building codes and regulations impact the smartification of buildings? Are there specific legal requirements or mandates for incorporating smart features in new construction or retrofitting existing buildings?

2.2.2 Workshop

The online workshop that was organized and is a pivotal component of this task, welcomed active participation from all partners, fostering inclusivity regardless of their role as a pilot or non-pilot. Employing the "MIRO" tool, the workshop was conducted through a video conference platform to facilitate seamless collaboration and to provide the ability to record participant responses.

To enhance diversity in perspectives, participants were strategically divided into three equally balanced groups. Notably, each group was intentionally composed of individuals from different organizations, ensuring a varied and engaging discussion. The groups were then allocated to separate virtual rooms during the workshop, providing them with dedicated time to deliberate on the various aspects emerging in the conversation.

The utilization of the "MIRO" tool involved the creation of three distinct boards, one for each group. Within each board, specific subsections were established to focus on the Drivers and Barriers, as well as Stakeholders and their Requirements. This approach allowed for a structured and efficient implementation of the collaborative analytical process.

An example of the board can be found bellow in Figure 2:

1. EVELIXIA_Task 1.1 workshop_Feb2024

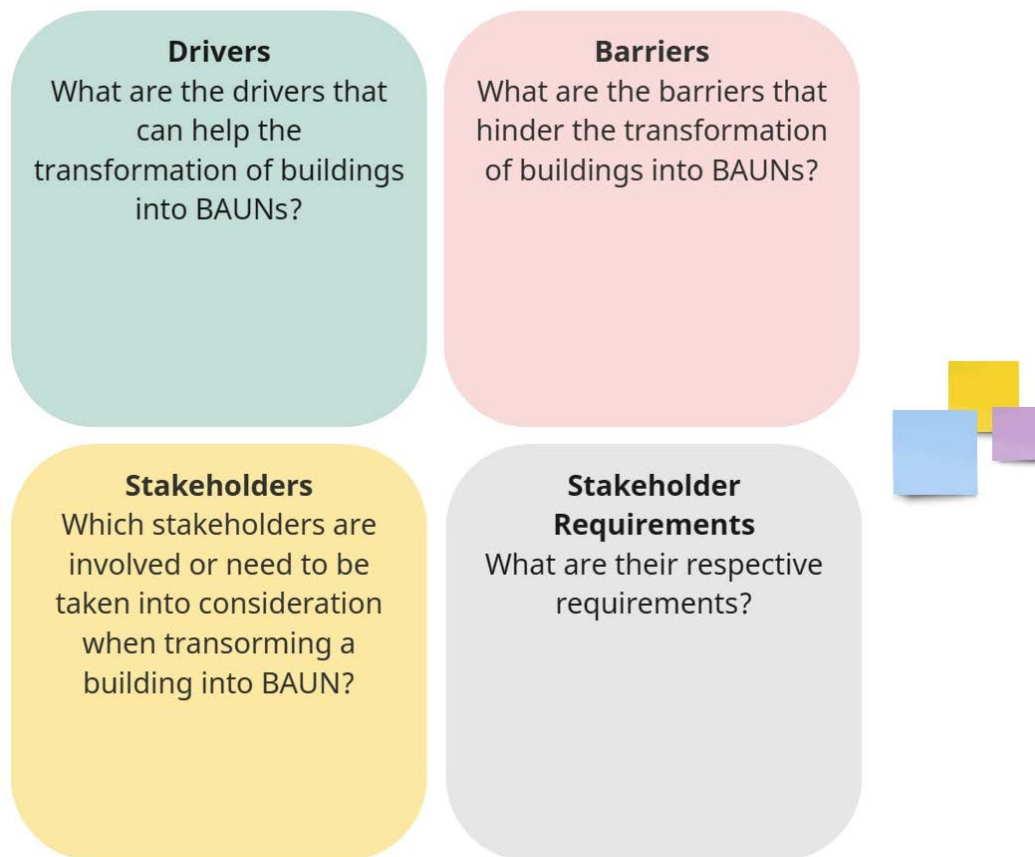


Figure 2. Miro Board used for the online workshop.

Each participant actively engaged in the workshop by expressing their thoughts on the ongoing topic using interactive "sticky notes". The workshop unfolded in two distinct sections, with the initial focus on identifying various Drivers and Barriers associated with BAUNs.

During the initial 15-minute brainstorming and data collection phase, each group independently explored Drivers and Barriers. Subsequently, all groups reconvened in the main conference room to collaboratively discuss key aspects and share opinions on the matter. The second section followed a similar format, with participants delving into the discussion on potential Stakeholders and their Requirements for smart building implementation.

3 WORKSHOP RESULTS

The resulting boards of the online workshop were collected and consolidated into a single database, and revealed interesting similarities across groups, highlighting common thoughts and responses among diverse partners. This organized approach provided valuable insights into priorities and critical aspects concerning the integration of smart buildings into BAUNs.

Examining the Drivers category, unanimous agreement emerged on the significance of integrating renewable energy into the grid, driven by the environmental impact and alignment with EU's net-zero future targets. Additionally, participants emphasized the positive influence of favourable regulations and legislation prevalent in many EU countries. The rapid evolution of technology in our era was also acknowledged as a crucial Driver for implementation.

Conversely, when addressing Barriers, participants recognized counterbalances. For instance, initially favourable regulations and legislation in some EU countries transformed into obstacles when taxation considerations were introduced. Despite the existence of advanced technologies, the high upfront costs associated with their implementation emerged as a significant Barrier. Other concerns included the lack of suitable business models and potential data privacy issues, highlighting the challenges posed by the relative newness and unexplored territory of BAUN implementation.

In the sections below, the initial results from the workshop are presented in tables. First the drivers and barriers that were identified by the participants are categorised according to which dimension of the PESTEL framework they fit best. Moreover, the stakeholder groups that were identified and their related requirements, according to the experts' opinions, are listed separately.

3.1 Drivers & Barriers

<i>Political</i>	
<i>Driver/Barrier</i>	Enhancement of smart technologies Recognized legislation Government incentives Bureaucratic challenges Regulatory challenges
<i>Economic</i>	
<i>Driver/Barrier</i>	Energy prices decrease/ cost saving Economic incentives Aids Energy market incentives Decreasing cost and generalization of rooftop solar PV panels Initial investment cost Technology cost Intensive investment Cost of building retrofitting Upfront cost for residents for technological solutions Market demand Financing
<i>Social</i>	
<i>Driver/Barrier</i>	Increasing consumer awareness Urbanization Citizen Engagement Sense of community Lack of awareness Stakeholder acceptance Stakeholders not understanding the importance of the end goal Fear of losing comfort
<i>Technological</i>	
<i>Driver/Barrier</i>	Increasing smartness of electricity grid Implementation of the SRI by Member States according to the latest EPBD revision Increasing utilities of renewable energies Development of business models Technological advancement/ Demonstration projects and use cases Infrastructure in remote areas Lack of well-established business models Lack of packaged and standardized solutions

<i>Environmental</i>	
<i>Driver/Barrier</i>	Energy security Favourable environmental impact Environmental sustainability as it encourages mor usage of renewable energy Renewable energy integration Data privacy and security concerns Taxation and Legislation in some countries
<i>Legal</i>	
<i>Driver/Barrier</i>	Sufficient subsidies for renewable energy Favourable regulation

3.2 Stakeholders & Requirements

1. Occupants and building stakeholders

- Building owners
- Building managers
- Building occupants/Tenants
- City residents

2. Technology and Industry Players

- Technology developers
- Smart technology manufacturers and distributors
- Technological providers
- Storage developers
- IT
- Architects
- RE developers

3. Government and Regulatory Bodies

- Community and environmental representatives
- City officials
- Local authorities
- Government

4. Energy management

- Energy providers
- Energy Managers
- DSO/TSO
- ESCOs City administrators (take part in the supervision process)
- Aggregators

5. Research and innovation

- Research institutes

Stakeholder Requirements

- Building owners/managers:
 - o Data security assurance
 - o Clear understanding of benefits and Return on Investment (ROI)
 - o Financial incentives covering BAUNs infrastructure
 - o Enhancement of occupants' satisfaction
 - o Real-time monitoring of energy prices
 - o Focus on comfort and quality of building usage
 - o Knowledge sharing with residents
 - o Granularity in flexibility markets
 - o Adequate remuneration for services
- Technology providers:
 - o Prioritization of data security
 - o Conducting thorough market research
 - o Scalability of solutions
 - o Interoperability in solution monitoring and maintenance
 - o Understanding the needs of stakeholders
 - o Addressing the lack of definition of flexibility solutions in the market
 - o Training building managers in relevant technologies
 - o Gathering feedback from occupants on service quality
- DSO/TSO:
 - o Ensuring security and reliability in BAUNs response
 - o Seamless integration into existing energy infrastructure and grid systems
 - o System stability and interoperability
 - o Facilitating data exchange securely
 - o Optimizing energy flux for efficiency
- Occupants:
 - o Assurance of comfort in the building
 - o Promotion of an energy-efficient and sustainable environment
 - o Visibility into energy usage and costs through real-time monitoring and feedback systems
 - o Economic benefits from energy savings and lower electricity bills
 - o Ensuring data privacy
- Owners:
 - o Access to investment aids

- o Profitability in implemented solutions
 - o Increase in property value
 - o Enhancement of overall life quality
 - o ESCOs/Energy managers/Aggregators:
 - o Development of profitable business models
 - o Access to advanced technological tools for building energy management
 - o Adequate volume of flexibility offered by the building
- Environmental representatives:
 - o Ensuring sustainable deployment of BAUNs to address climate change
- End-users:
 - o Streamlined processes for purchasing and installing solutions
- City officials:
 - o Alignment with community actions
 - o Infrastructure development support
 - o Community outreach and collaboration with research institutes

4 PESTEL ANALYSIS

After the processes of desk research and data collection from the questionnaire and workshop were concluded, the final PESTEL analysis was conducted and the resulting factors in each dimension are described in this section. For each of the PESTEL dimensions, first a general overview at the EU level is presented and then the more specific national context for each of the pilot case countries is described.

4.1 Political

The EU has established a comprehensive policy framework to enhance energy efficiency and smartification of buildings. The key instrument in this regard is the Energy Performance of Buildings Directive (EPBD) [1], which is being recast to increase the rate and depth of renovation of Europe's existing building stock. This is a crucial component of the EU's Renovation Wave Strategy. The EPBD, along with the Energy Efficiency Directive (EED) [2], promotes policies aimed at achieving a highly energy-efficient and decarbonised building stock by 2050. The EU building stock accounts for about 40% of total greenhouse gas emissions, and to achieve climate neutrality by 2050, the EU must significantly increase its rate and depth of renovation. Key initiatives include the EU Green Deal, the Renovation Wave, and the Fit-for-55 package. These initiatives and regulations serve as a guidebook for building energy efficiency [3].

One other pivotal tool in the EU's policy arsenal for smart building promotion is the development and uptake of the Smart Readiness Indicator (SRI). This indicator evaluated a building's potential 'smartness' by assessing the functionality levels of various services, encompassing heating, cooling, lighting, energy generation, and more. The higher the functionality level, the higher the SRI score, indicating greater benefits to occupants and the grid. Expectations were set for European Commission acts in 2020 to regulate and implement the SRI [6].

The SRI aims to inform building stakeholders about a structure's capabilities, integrating the building sector into electricity systems and fostering awareness and investment in smart technologies. The emphasis is not only on residential spaces but also on commercial buildings, recognizing the importance for both occupants and investors [6].

Additionally, acknowledging the crucial role of smart technologies in decarbonizing the building and energy sectors, the focus expanded to leverage buildings as efficient micro-energy hubs. These buildings would consume, produce, store, and supply energy, contributing to a more flexible and efficient energy system. The intent is to balance the future energy landscape, dominated by variable renewables, through storage and demand response mechanisms, ensuring comfortable and healthy environments for occupants.

Simultaneously, changes in the EPBD recognized the evolving transportation landscape, integrating provisions for charging infrastructure for e-mobility in buildings. By 2025, Member States are mandated to establish requirements for charging points in non-residential buildings with over 20 parking spaces, simplifying installation processes, and necessitating ducting infrastructure in new or renovated buildings with over 10 parking spaces [5]. The European Union's policy framework for the smartification of buildings, while comprehensive, faces several barriers that hinder its full implementation [7].

Another significant barrier is the lack of necessary policy competences at the local level. Many local administrations face considerable challenges in developing smart cities due to their national frameworks. Some administrations are unable to use local fiscal incentives or are not responsible for key local issues affecting the city, such as the introduction of congestion charges or taxes on the use of specific local resources. The landscape in the EU of the powers of local authorities is very heterogeneous.

Furthermore, administrative burdens often prevail, often from obsolete rules. The adoption of coherent standard procedures across city departments is recommended to facilitate the introduction of innovations.

When contemplating the transition of smart buildings into BAUNs, various factors drive decision-making processes across EU countries. While these nations operate under overarching regulations, their individual legislations diverge. Nevertheless, a common thread unites them in the promotion of advanced smart technologies, including:

- Prioritizing sustainable practices and resource optimization.
- Emphasizing interconnectedness and data exchange capabilities to enhance operational efficiency.
- Implementing automated systems to streamline building functions and enhance user experience.

- Integrating buildings into intelligent grid systems for optimized energy distribution and management.
- Focusing on creating environments conducive to occupant satisfaction and health.
- Leveraging data analytics for informed decision-making and proactive maintenance strategies.

Table 2 Political factors in the participating countries

PESTEL Dimension	France	Spain	Italy
Political	Proactive alignment with EU directives, particularly EPBD, showcasing commitment to energy performance improvement. Collaboration between government, industry players, and initiatives like 'Ready to services' label, 'NF Habitat HQE' certification.	Alignment with EU directives such as EED and EPBD, reflected in the integration of EPBD into the Technical Building Code. Focus on self-consumption regulations with adaptability challenges indicating the need for further regulatory refinement.	Successful transposition of EU directives into national law with standards like UNI EN ISO 52120-1 and policy schemes supporting smart buildings. Implementation of mandatory automation levels in new constructions and funding initiatives like 'Superbonus 110%' driving smart building development.
	Romania	Finland	Austria
	Legislative amendments emphasizing smart buildings, supported by measures to encourage prosumers and foster sustainable energy landscapes. Inclusion of smart building technologies within strategic initiatives like the National Recovery and Resilience Plan for environmental sustainability.	Active participation in EU initiatives like SRI with pending decisions on mandatory vs. voluntary adoption, reflecting a nuanced regulatory approach. Political commitment to adopting smart solutions for enhancing energy efficiency and sustainability in line with European standards.	Strong alignment with EU directives like EPBD and NZEB targets, managed through institutions like the Austrian Institute of Construction Engineering. Implementation of Digital Action Plan and Digital Austria initiative supporting digitization and fostering competitiveness and innovation.

4.1.1 France

France has shown proactive efforts in aligning its national legislation with EU directives, particularly the EPBD. The country is at the forefront of transposing EPBD, showcasing a commitment to improving buildings' energy performance. While there's no formal definition for smart buildings in French law, the government and stakeholders are actively studying the concept. Initiatives such as the 'Ready to services' label and 'NF Habitat HQE' certification, along with the creation of a Massive Open Online Course (MOOC), reflect collaborative efforts between government and industry players like the Smart Building Alliance (SBA)

and Alliance HQEGBC. The implementation of the SRI, the 'Décret BACS,' and the extensive smart meter rollout demonstrate France's commitment to advancing smart building technologies and energy efficiency. The demand response mechanisms and the development of flexibility in tertiary buildings further indicate a forward-looking approach in the political landscape.

Additionally, policies like the Tertiary Decrees, Building Environmental Regulation, and the Climate and Resilience Law emphasize energy performance targets, renewable energy integration, and photovoltaic adoption. Overall, the regulatory framework aligns with EU goals, setting clear guidelines for the smart building sector.

4.1.2 Spain

In the political sphere, Spain exhibits a commendable effort in aligning with European Union directives related to smart buildings. The transposition of crucial legislation, such as the EED and the EPBD, into national law underscores a commitment to achieving energy and climate objectives. Moreover, the integration of the EPBD into the Technical Building Code (Código Técnico de la Edificación, CTE) demonstrates a meticulous approach to adapting European legislation at the national level, ensuring a coherent framework for the development and implementation of smart building technologies.

Additionally, a focus is placed onto self-consumption (SC) and Collective Self-Consumption (CSC) regulations that highlight the priorities within Spain's regulatory landscape. The adjustment of maximum distances for CSC, reveals a proactive stance in adapting regulations to accommodate technological advancements. However, it also indicates ongoing challenges in fully consolidating a regulatory framework for energy flexibility markets. This showcases a nuanced political dimension where adaptability coexists with the need for further regulatory refinement to fully unleash the potential of smart building technologies.

4.1.3 Italy

In Italy, the political landscape for smart buildings is shaped by the adoption and implementation of European Union directives. The EU legislation regarding Smart Buildings has been successfully transposed into national law through the standard UNI EN ISO 52120-1. Enforced since November 4, 2022, this standard replaces UNI

EN 15232-1:2017, aligning with the European Directive EPBD 2010/31/EU on the energy performance of buildings and its subsequent update by Directive 2018/844. The UNI EN ISO 52120-1 establishes a comprehensive framework and procedures for the energy performance of buildings, specifically focusing on the contribution of automation, control, and technical management. This standard categorizes BACS into four classes (D to A), each representing different levels of energy efficiency and applicability to both residential and non-residential buildings.

- **Class A ("High Energy Performance"):** State-of-the-art Smart Building with maximum performance.
- **Class B ("Advanced"):** Closer to the Smart Building concept with integrated climate regulation.
- **Class C ("Standard"):** Minimum BACS devices for basic automation.
- **Class D ("Non-Energy Efficient"):** Traditional technical systems without automation.

Moreover, Italy has reinforced these standards with specific policy schemes. M.D. 26/06/2015 mandates a minimum level of automation (Class B) for new or renovated non-residential buildings. Some regions extend this obligation to new residential constructions at Class C. M.D. 16/2/2016 "Conto Termico 2.0" integrates BACS into interventions for increasing energy efficiency in existing buildings, requiring Class B for public administration funds.

Moreover, Italy has successfully implemented the EU legislation on Smart Buildings through the "Strategia per la riqualificazione energetica del parco immobiliare nazionale" (STREPIN), aligning with EU directives. However, the new National Energy and Climate Plan (NECP) lacks more ambitious targets, posing challenges for future advancements. The 'Superbonus 110%' initiative, introduced in May 2020, serves as a key policy supporting smart building development, covering aspects like building automation and renewable energy integration.

4.1.4 Romania

In a strategic move towards aligning with European Commission directives, Romania has taken significant legislative steps to propel its building sector into the realm of smart technologies. The enactment of Law no. 101 on July 1, 2020, marked a pivotal moment as it amended Law no. 372/2005 on the energy performance of buildings. This amendment introduced a new chapter specifically dedicated to Smart Buildings, reflecting the country's commitment to staying at the forefront of evolving energy efficiency standards.

Reinforcing this legislative foundation are additional measures, such as Order 95/2022 and Law of Electrical Energy 123/2012, both of which bolster support for prosumers by implementing compensation mechanisms. These provisions not only demonstrate Romania's dedication to embracing smart building solutions but also emphasize a commitment to fostering a dynamic and sustainable energy landscape.

Furthermore, the nation's political landscape has positioned smart buildings as a focal point within the National Recovery and Resilience Plan. This strategic initiative emphasizes the importance of the Green Transition and incorporates a dedicated component known as the Renovation Wave. Within this framework, the emphasis on smart building technologies emerges as a key driver in achieving environmental sustainability and economic resilience.

4.1.5 Finland

In Finland, the political landscape plays a crucial role in shaping the trajectory of smart buildings. The country is actively participating in the European initiative of the SRI. The decision on whether SRI will be mandatory or voluntary is pending, reflecting a nuanced approach to regulation. Finland's political framework emphasizes a commitment to adopting smart solutions that enhance energy efficiency and align with evolving European standards. The national policy landscape is adapting to the changing dynamics of the construction industry and the imperative of sustainability.

4.1.6 Austria

Austria's political landscape exhibits a strong alignment with EU directives, particularly in the realm of smart buildings. The EPBD has been transposed into national law, fostering a harmonized approach across the nine provinces. The Austrian Institute of Construction Engineering (OIB) plays a pivotal role in managing the implementation process, as reflected in the OIB Guideline 6. The political commitment extends to long-term goals, with the national plan targeting nearly zero-energy buildings (NZEB) by 2020 and ongoing preparations for 2030 and beyond, in line with global climate agreements.

The implementation of the Digital Action Plan and the overarching Digital Austria initiative underscores Austria's commitment to a technologically advanced and

digitized future. The plan not only supports e-Government solutions but also facilitates the creation of a digitalization-friendly environment, aligning with the nation's vision for competitiveness through targeted digitization.

Specifically, the impact of the political framework on the pilot case of Austria is thought to be positive, with the Digital Action Plan providing an effective structure for implementing digitization projects across industries, fostering competitiveness and innovation.

4.2 Economic

The economic dimension plays a significant role in the adoption and implementation of smart buildings in the EU. The related factors can act as both drivers and barriers, influencing the pace and extent of smart building adoption. The economic viability of smart buildings is one of the key drivers. The leading countries in terms of smart-readiness, such as Sweden, Finland, Denmark, and the Netherlands, have implemented enabling measures. These policies have proven the economic viability of smart buildings, showcasing a series of progressive policies and innovative front-runner projects. The economic benefits of smart buildings, such as energy savings, increased property values, and improved occupant comfort and productivity, are becoming increasingly recognized. This recognition is driving investment in smart building technologies and practices [8]. The smartification of buildings encounters economic hurdles that impede its progress. Chief among these challenges is the sluggish adoption of Information and Communication Technology (ICT) and smart solutions within the building sector. Despite the promise of smart building technology to curtail energy consumption and embrace renewable energy sources, the sector, being Europe's largest energy consumer, has been hesitant to embrace these advancements. This reluctance stems partly from the substantial initial costs associated with implementing such technologies. The upfront investment required can be daunting for building owners and operators, deterring them from taking the leap [8]. Moreover, the lengthy payback period exacerbates this disincentive, further dissuading investment. Income disparities also come into play, as lower-income households may stand to gain from job opportunities created by platform work, yet simultaneously endure adverse effects from unfavourable employment conditions.

Another significant barrier is the lack of necessary financial incentives at the local level. Many local administrations face considerable challenges in developing smart cities due to their national frameworks. Some administrations are unable to use local fiscal incentives or are not responsible for key local issues affecting the city, such as the introduction of congestion charges or taxes on the use of specific local resources [8].

Furthermore, the discrepancy between the techno-economic potential and actual market behaviour has been coined as the ‘energy efficiency gap’ and implies that non-technical hurdles are preventing the large-scale diffusion [9]. This gap highlights the need for more effective policies and measures to overcome these economic barriers and fully realize the potential of smart buildings in the EU. The energy efficiency gap can be attributed to a variety of factors, including market failures, behavioural biases, and regulatory barriers [10]. Market failures, such as information asymmetry and externalities, can prevent the efficient allocation of resources towards energy-efficient technologies and practices.

De-risking Energy Efficiency Platform (DEEP)

Within the EU, the De-risking Energy Efficiency Platform (DEEP) stands as a pivotal resource, offering a comprehensive open-source database. This repository encompasses intricate data and analyses pertaining to over 10,000 energy efficiency projects linked to both industrial and buildings sectors. Its primary function revolves around establishing performance track records, thereby facilitating thorough assessments of risks and benefits inherent in energy efficiency investments across Europe. DEEP serves as a valuable tool not only for project developers but also for financiers and investors, empowering them to make informed decisions within this complex landscape. [5].

Smart Finance for Smart Buildings (SFSB)

In response to the Clean Energy Package, the European Commission has spearheaded the creation of the Smart Finance for Smart Buildings (SFSB) initiative, a pioneering financial endeavour. Its overarching goal is to heighten the allure of energy efficiency investments in buildings for private investors, leveraging EU funds intelligently. The initiative's strategic framework entails several pivotal steps, including optimizing the utilization of public funds, facilitating and consolidating project development through streamlined processes like one-stop-

shops, and mitigating risks associated with energy efficiency investments. Through SFSB, a targeted unlocking of €10 billion from both private and public coffers is envisaged, with the potential to generate up to 220,000 employment opportunities. Over time, this initiative is poised to significantly augment the renovation rate, foster job creation, and mitigate the scourge of energy poverty. By effectively de-risking investments in the building sector, SFSB furnishes investors with enhanced clarity regarding the associated risks and rewards of energy efficiency endeavours. Additionally, the initiative lends support to the adoption of Energy Performance Contracts (EPCs) within the public sector. These contracts offer a pragmatic avenue for enhancing the energy efficiency of public buildings and infrastructures, with the initial investment underwritten by a private partner and subsequently reimbursed through assured energy savings [5].

From an economic standpoint, the implementation of BAUNs (Building-Active Utility Nodes) presents a direct correlation with long-term cost savings. Installing solar photovoltaics (PVs) on building rooftops, for instance, allows for the generation of green energy that can be fed into the grid, thereby potentially reducing electricity prices for the entire community. Additionally, residents within the BAUN complex can benefit from decreased electricity bills because of this renewable energy integration.

Economic incentives, including various government aids, play a pivotal role in encouraging the adoption of renewable energy solutions such as solar PVs. These incentives serve to offset upfront costs and facilitate significant investments for BAUN residents, making the transition to sustainable energy sources more financially feasible.

Moreover, the conversion of a smart building into BAUNs not only leads to community cost savings but also unlocks opportunities in the energy market for residents and industry experts alike. Despite the promising economic benefits, however, challenges exist that can hinder progress and pose barriers to implementation.

Table 3 Economic factors in the participating countries

PESTEL Dimensi on	France	Spain	Italy
Econo- mic	Implementation of economic incentives like 'Décret BACS' for building automation. Commitment to smart meter rollout and demand response mechanisms. Lack of direct incentive schemes for smart buildings.	Integration of smart building initiatives within broader legal frameworks like Ley 10/2022. Emphasis on rehabilitation activities and digitalization of buildings. Nuanced economic incentives including grants for rehabilitation and renewable energy.	Preemptive economic approach with incentives linked to energy efficiency legislation. Tax incentives like 'Superbonus 110%' driving smart building adoption. Legislative support for renewable energy communities contributing indirectly to smart building development.
	Romania	Finland	Austria
	Suite of financial incentives including Regional Operational Program and Modernisation Fund. Allocation of funds within National Recovery and Resilience Plan for smart building projects. Rigorous cost-benefit analysis to assess economic feasibility.	Reliance on existing support schemes for energy efficiency improvements. Consideration of local energy dynamics like electricity prices and climatic conditions. Focus on long-term energy savings rather than direct financial incentives.	Multifaceted economic considerations including costs, energy savings, and market demand. Federal and regional funding programs supporting smart building adoption. Ongoing pilot case influenced by economic feasibility and potential revenue opportunities.

4.2.1 France

France has implemented various economic incentives to encourage the development and uptake of smart buildings. The 'Décret BACS' mandates certain tertiary buildings to be equipped with a building automation and control system by 2025. The completion of the smart meter rollout and the focus on demand response mechanisms, with a target of 5 times the current capacity by 2050, illustrate France's commitment to fostering a technologically advanced and energy-efficient built environment. However, it's worth noting that specific economic incentives for smart buildings' development are lacking. While financial promotions exist for photovoltaic panels, there's no direct incentive scheme for smart buildings.

Factors influencing the economic feasibility of BAUNs in France involve investment costs, operational impacts, and regulatory frameworks. The pilot case by ENTECH identifies potential revenue streams through reduced consumption bills, electricity sales, and services like frequency regulation. National and regional investment incentives support smart building projects, creating a conducive economic

environment. The financial benefits accrue to building managers, emphasizing a viable economic model within the regulatory framework.

4.2.2 Spain

For the case of Spain, the factors shaping the feasibility of BAUNs entail the deployment and maintenance costs, aids, and electricity pricing, which underscores the complexity inherent in assessing economic viability.

The absence of specific policy schemes directly supporting smart buildings is complemented by the broader context of Ley 10/2022. This legal framework stimulates building rehabilitation activities and contemplates the digitalization of new and existing buildings. Such a multifaceted approach acknowledges that economic viability extends beyond direct incentives, encompassing broader initiatives that foster digitalization within the construction sector.

Moreover, various nuanced economic incentives are highlighted, such as grants for rehabilitation, renewable energy installations, and pilot projects by energy communities. These incentives provide a comprehensive view of the economic landscape, where support is channelled not only towards smart building technologies but also towards broader energy efficiency and renewable energy goals.

4.2.3 Italy

Italy's economic landscape reflects a pre-emptive approach to incentivize the development and uptake of smart buildings, aligning with energy efficiency objectives. Economic incentives and support measures are woven into legislative frameworks.

D.M. 06/08/2020 "Requisiti Ecobonus" links the adoption of Building Automation in residential buildings (Class B) to incentives, offering a 65% rebate and an impressive 110% if tied to Ecobonus. Additionally, D.M. 11/10/2017 "CAM" recognizes the installation of a monitoring system connected to BACS as a rewarding criterion for energy efficiency (Class A).

These economic incentives and support measures showcase Italy's commitment to fostering smart building technologies. They not only provide financial benefits for adopting automation but also create a compelling case for stakeholders to

embrace advanced systems, contributing to both energy efficiency and the national transition toward smarter, sustainable buildings.

Economic incentives in Italy, such as the 'Superbonus 110%,' act as a significant driver for smart building development. This tax incentive scheme covers costs for energy-efficient and structural improvements, including building automation and photovoltaic systems. Legislative Decree No. 162 of 2019 introduces incentives for renewable energy communities, providing a premium tariff for self-consumed electrical energy, indirectly supporting the integration of Building Automation and Urban Networks (BAUNs) with renewable energy systems.

4.2.4 Romania

Romania has strategically positioned itself to encourage the adoption of smart building technologies by providing a suite of financial incentives. Through initiatives like the Regional Operational Program, ElectricUp, and the Modernisation Fund, the country is actively fostering an environment conducive to the development of smart and sustainable buildings. Notably, the National Recovery and Resilience Plan has earmarked funds specifically for the renovation wave, emphasizing a commitment to supporting projects that integrate intelligent technologies.

As Romania delves into the realm of Building Automation and Control Systems (BAUNs), a critical aspect under scrutiny is their economic feasibility. This assessment involves a comprehensive evaluation based on key performance indicators, including energy savings, revenue generated from demand response services, and income derived from excess electricity. The pilot case, serving as a testing ground, anticipates positive impacts on economic feasibility, signalling a promising outlook for the integration of BAUNs in the broader context of smart building development.

Integral to this evaluation is a rigorous cost-benefit analysis, wherein the financial benefits of smart building technologies come to the forefront. These benefits encompass a spectrum of advantages, ranging from tangible cost savings and reduced energy and water consumption to the less apparent yet impactful reduction in maintenance costs. Importantly, the overall efficiency of buildings is poised for improvement, marking a transformative shift towards a more sustainable and economically viable built environment. Romania's approach,

underpinned by a robust framework of financial incentives and a meticulous assessment of economic feasibility, reflects a commitment to propelling smart building technologies into the mainstream, ensuring a harmonious balance between environmental sustainability and economic prudence.

4.2.5 Finland

Economic considerations in the Finnish pilot case highlight the multifaceted factors influencing the feasibility of BAUNS. The reliance on locally produced thermal energy, especially through heat pumps, positions electricity prices as a key determinant of economic viability. The economic feasibility of PV plants is influenced not only by electricity prices but also by climatic conditions, roof orientation, and self-consumption patterns. While there are no direct economic incentives for smart buildings, existing support schemes for energy efficiency improvements indirectly contribute to the development and uptake of BAUNS.

The pilot case underscores the interconnectedness of economic factors with energy market dynamics. The volatility in electrical energy prices, triggered by factors such as the growth of wind energy, commissioning of nuclear plants, and geopolitical events like the Ukraine war, has introduced new dimensions to the economic landscape. Despite the absence of direct financial benefits for occupants in rental properties, the focus on long-term energy savings can justify the adoption of smart solutions.

4.2.6 Austria

Economic considerations for BAUNs in Austria are multifaceted. The feasibility of BAUNs to generate revenue hinges on factors such as costs, energy savings, safety enhancements, market demand, and regulatory incentives. The costs associated with BAUNs development encompass materials, labour, and maintenance, and these factors are critical in conducting a thorough feasibility study. The potential for energy savings, improved safety, and market demand present revenue opportunities.

Austria offers economic incentives and support measures for smart buildings through federal funding programs and state-level subsidies. The Climate and Energy Fund, along with regional subsidies, encourages the adoption of building

automation, fostering financial support and contributing to the economic viability of BAUNS.

The pilot case, still in its early stages, is influenced by these economic factors. As the project progresses, a more comprehensive understanding of its economic feasibility and potential financial benefits will emerge.

4.3 Social

The social dimension plays an important role in the adoption and implementation of smart buildings in the European Union (EU). These types of factors can act as both drivers and barriers, influencing the pace and extent of smart building adoption. Public participation, for instance, is a powerful driver and is often utilized to overcome barriers. Active involvement of the public in the planning and implementation of smart city projects can foster acceptance and uptake of smart building technologies. Cooperation between different stakeholders, including government agencies, private sector companies, and civil society, is another key driver [11]. Such collaboration can facilitate knowledge- and resource-sharing, resulting in accelerated adoption of smart building concepts. However, social factors can also pose barriers to the smartification of buildings. Communication between project participants and the public is often a challenge. Misunderstandings or lack of awareness about the benefits and operation of smart buildings can hinder their acceptance and uptake. Behavioural biases, such as loss aversion and status quo bias, can also hinder the adoption of energy-efficient technologies and practices.

There are two significant factors with broad relevance: the ***user-friendliness*** and ***accessibility of applications***, and ***the awareness raised*** about their existence and added value. User-friendly and intuitive applications are crucial to avoid excluding less digitally literate individuals [12]. Complex and time-consuming login or access procedures can discourage advanced users as well. These complications often occur in e-administration or e-banking, where privacy and safety provisions may require multiple steps. In some cases, the involvement of trained staff is key, especially in technologically complex solutions like remote patient monitoring. However, there are recent initiatives in the public sector, such as the network of Public Innovation Labs in France, that involve end users in the co-design process of new digital services [12].

Furthermore, some applications and services are still not optimized for mobile devices, despite the ubiquity of such devices. Additionally, not all public administrations are aware of guidelines and rules for making web services accessible to people with disabilities, despite the EU Web Accessibility Directive highlighting accessibility rules.

Awareness is crucial because services and opportunities may go unnoticed. This is particularly true for new public services and participatory tools, where resources are needed for effective advertising [7]. However, different target groups require different communication tools. While social media and expert/sectorial channels can engage a large segment of society, others may require traditional tools like TV, printed media, and in-person engagement. Cities like Nantes in France provide examples of effectively informing their elderly population about available opportunities. Awareness is necessary to address doubts and build trust, especially among those who fear the side effects or threats of digital innovation [10].

Data protection and cybersecurity standards are important for the successful implementation of smart city solutions. Trust in these aspects helps mitigate risks and regulates the use of data. For instance, the deployment of smart meters depends on regulatory arrangements that ensure data privacy and security. Transparency and accountability of local governments and service providers, especially regarding data use and sharing, along with the impact of e-participation on decision-making, contribute to trust and participatory aspects [8].

The general level of digital skills among users is another external factor. Negative outcomes are more likely when users are unfamiliar with the technology and unable to use it effectively. User-friendly design can partially mitigate this issue.

Smart city policies impact different groups in diverse ways. Less digitally educated individuals, particularly the elderly, face challenges using certain ICT applications due to a lack of smart devices or low digital literacy [7]. Digital proficiency doesn't always guarantee easier access to smart city services; for example, young people may be unaware of e-administration services. Simultaneously, younger generations are more exposed to the adverse effects of digital applications, such as privacy concerns and cybercrime.

Automation and lack of personal interactions with authorities can affect households at a lower socio-economic level. Residential status is a factor to consider, as residents, commuters, and tourists experience impacts differently.

Environmental restrictions may limit commuters' travel options, while increased on-demand mobility services may negatively affect residents. Tourists benefit from shared services and alternative accommodations. Entrepreneurs and owners of small businesses are also affected differently. They can benefit from e-commerce and platform services but face competition from larger companies and new start-ups [8].

Overall, disadvantages and exclusion often result from a combination of factors across demographic categories. For example, migrants may face difficulties understanding digital services due to language barriers.

Barriers include concerns regarding data security, privacy, and control over smart systems, as well as differing perceptions of comfort among occupants and potential lock-in effects related to future software updates and equipment upgrades.

Drivers for smart building solutions include a deeper understanding of occupant behaviour and catering to specific demographic groups, such as the elderly or students. These solutions can compensate for functional/mental decline in the elderly. The COVID-19 pandemic has also accelerated the adoption of smart technologies in existing buildings due to increased awareness of indoor air quality. Within the social domain, acquiring insights into the production and the direct and indirect impact of renewable energy emerges as a powerful tool to raise consumer awareness about energy consumption and its environmental consequences. This heightened awareness has the potential to foster a sense of community and sensitize end-users to the broader implications of their energy consumption habits. Moreover, addressing issues like energy security, energy poverty, and concerns related to potential comfort loss becomes achievable through the implementation of various techniques aimed at cultivating a more sustainable environment via renewable energy solutions.

However, a notable challenge persists on the flip side. Despite the potential benefits, there is a lack of an efficient mechanism for effectively communicating the profound effects of energy consumption to residents and other stakeholders. This challenge extends beyond individual residents to include various potential stakeholders who may not fully comprehend the significance of the overarching goal of building smartification and transforming these structures into active utility nodes. Bridging this communication gap is imperative to overcoming social

barriers and unlocking the holistic potential of integrating renewable energy solutions into the fabric of our communities.

Table 4 Social factors in the participating countries

PESTEL Dimensi on	France	Spain	Italy
	Limited public awareness necessitates increased education and awareness campaigns. Concerns about smart metering, data privacy, and health impact public acceptance. Legislative changes and awareness initiatives are expected to drive public understanding and acceptance.	Positive societal inclination towards sustainability but cautious approach towards data privacy. Social dynamics vary based on property ownership structure, influencing decision-making processes. Robust privacy measures are essential for widespread public acceptance of smart building technologies.	No Information provided
Social	Romania	Finland	Austria
	Challenges in public acceptance due to factors like delay in technology adoption, perceived high costs, and data security concerns. Engagement efforts with students show promise but broader acceptance remains a gap. Addressing data security concerns is crucial for fostering public trust and acceptance.	Limited public awareness necessitates broader education on long-term benefits. Privacy and security concerns are focal points, requiring proactive measures. Social dynamics of residents' influence system adoption, highlighting the importance of ease of use and comfort in smart building design.	Evolving public awareness with notable interest from younger generations. Concerns about data privacy and security are pronounced, especially among older demographics. Community engagement is crucial for shaping social interactions and addressing public concerns.

4.3.1 France

Public awareness of smart buildings in France is not widespread, though efforts are being made to increase it. The ongoing revision of the EPBD and the SRI are expected to enhance the concept's visibility. Initiatives like the EcoWatt campaign address energy flexibility, but manual interventions are still prevalent, lacking full automation through smart technologies. Concerns about smart meters exist in the population, driven by issues such as data privacy and health. Overall, the level of public acceptance and understanding of smart buildings is anticipated to grow, driven by legislative changes and awareness campaigns.

4.3.2 Spain

The social dimension of smart building implementation in Spain is intricately intertwined with public awareness, acceptance, and the dynamics of social interactions. The positive reception of renewable energy and energy efficiency installations within society are prevalent. This positive sentiment towards green technologies reflects a societal inclination towards sustainability.

However, critical social considerations, particularly concerning data privacy are also put under the spotlight. The acknowledgment of data privacy as a significant concern underpins the importance of addressing societal apprehensions surrounding smart building technologies. The public's cautious approach due to potential data privacy issues implies that technological advancements need to be accompanied by robust privacy measures to ensure widespread acceptance.

The insight into decision-making processes, where consensus is challenging within property communities but smoother with a single owner, reveals the nuanced social dynamics at play. Understanding these dynamics is crucial for designing implementation strategies that consider the social fabric and account for varying levels of decision-making complexity based on the ownership structure.

4.3.3 Romania

Romania seems to grapple with a notable challenge – a lack of public acceptance. This tepid reception can be attributed to various factors, including a delay in the adoption of cutting-edge technologies, the pressing and ongoing need for renovations, perceived high costs, and a dearth of solutions tailored to local conditions.

Efforts to engage the public, particularly through student involvement in demo pilots, have yielded positive results within the confines of student hostels. These initiatives have demonstrated a tangible impact on social interactions, showcasing the potential benefits of smart building technologies. However, the broader challenge persists, indicating a gap in translating positive experiences within specific contexts to wider public acceptance.

Central to public apprehension are concerns regarding data security, particularly in relation to the implementation of smart meters. The slow pace of smart meter installation compounds these worries. In response, the pilot case has proactively addressed these concerns by establishing secure communication lines. This

strategic move not only addresses the immediate apprehensions surrounding data security but also sets a precedent for responsible and secure deployment of smart technologies.

As Romania struggles with the complexities of fostering public acceptance, the lessons learned from student engagement and the targeted resolution of concerns related to data security present valuable insights. Bridging this acceptance gap requires a multifaceted approach that not only showcases the tangible benefits of smart buildings but also addresses the specific apprehensions of the Romanian public. In doing so, Romania can pave the way for a more inclusive and receptive environment for the integration of smart building technologies into the fabric of everyday life.

4.3.4 Finland

Public awareness in Finland, while currently limited, is gradually expanding beyond building industry professionals. The acceptance of smart solutions is generally positive, contingent on the perceived enhancements to building comfort and operability. However, cost remains a limiting factor for many consumers, indicating a need for broader education and awareness campaigns to highlight the long-term benefits.

Privacy and security concerns have emerged as focal points of public discourse. Initiatives to educate building automation professionals on cybersecurity issues underscore a proactive approach to address potential challenges. The social interactions and relationships of residents play a crucial role in the implementation of smart buildings. Instructions provided to residents for system use, coupled with motivations such as ease of use, comfort, and competitive advantages, contribute to the overall social dynamics of smart building adoption.

4.3.5 Austria

Public awareness and acceptance of smart buildings in Austria are evolving. While no specific survey exists, there is a notable interest among the younger generation, with Smart Homes garnering substantial attention. However, as the influence of data networking grows, concerns about data privacy and security become more pronounced. The 50+ generation exhibits a positive attitude toward the Smart City concept, yet scepticism persists, particularly concerning online transactions.

Privacy and security issues, along with external influence, are key concerns expressed by the public. The pilot case acknowledges the critical role of community engagement in shaping social interactions.

4.4 Technological

Technological advancements play a crucial role in driving the adoption of smart buildings, acting as active utility nodes for the grid. A prime example is the integration of Building Automation and Control Systems (BACS), which significantly enhance building energy efficiency. In 2018, there was an expanded requirement to install BACS in non-residential buildings with heating, ventilation, and air-conditioning systems exceeding specific outputs. BACS encompass various elements, including products, software, and engineering services, aimed at ensuring the efficient, safe, and economical operation of technical building systems through automated controls and manual management.

The addition of energy storage amplifies system flexibility by reducing peak loads or filling valleys. The choice of energy storage technology is influenced by factors such as power and energy capacity, availability period, installation space, life cycles, efficiency, and cost. Implementing controllable load and supply assets allows aggregators to contribute to power system flexibility by providing virtual inertia [13]. System safety, defined as the absence of catastrophic errors, and security, addressing unauthorized access to confidential information, are crucial considerations [13]. Cybersecurity, in particular, poses a significant barrier for consumers looking to implement Demand Response (DR), especially for industrial consumers concerned about revealing confidential business operations through electricity consumption data.

Numerous studies on smart cities and buildings emphasize the intensive use of Information and Communication Technologies (ICT). In cities, ICTs optimize services, enhance information accessibility, encourage public participation, integrate intelligence and sustainability, and improve overall quality of life. In buildings, the focus is on connecting systems and stakeholders through Building Automation Systems (BAS) [14]. Smart buildings are foundational to smart cities, and their integration into the smart built environment is dependent on the city's intelligent infrastructure, especially ICT and smart grids [15].

The evolution of this integration demands the development and improvement of technologies, tools, and methods based on integrated, transparent, and comprehensive approaches. Artificial intelligence technologies, along with increased processing and storage capacity, contribute to expanding systems' ability to interact and meet stakeholder expectations [15].

However, critical challenges persist in the implementation of smart building technologies, particularly in existing infrastructure and remote areas. Remodelling existing infrastructure presents challenges due to integrity issues and the need to align with pre-existing regulations. Retrofitting older buildings to meet smart building standards may require overcoming structural and technological hurdles. Infrastructure in remote areas often lacks necessary connectivity, hindering the efficient contribution of potential energy surplus to the grid. Geographical isolation can impede the integration of renewable energy technologies and create obstacles in maintaining and monitoring implemented systems.

While technological innovation is crucial, the development of robust business models is equally critical. The lack of fully developed business models in the smart buildings sector can serve as both a driver and a barrier. Progress in developing these models demonstrates a positive trajectory, but the lack of standardized procedures and information can impede widespread adoption.

Older buildings may lack the infrastructure for seamless integration with smart technologies, requiring upgrades and overcoming compatibility issues, potentially involving extensive renovations. Connecting remote areas to the grid presents unique challenges, as establishing the necessary infrastructure for transmitting surplus energy can be logistically and economically challenging, impacting the feasibility of renewable energy projects.

Table 5 Technological factors in the participating countries

PESTEL Dimension	France	Spain	Italy
Techno- logical	Robust technological landscape represented by organizations like the Smart Building Alliance. Advanced tools like the GOFLEX tool demonstrate commitment to technological advancements.	Availability of diverse technological solutions for smart buildings, although integration complexities exist. Forward-looking perspective towards continuous technological evolution.	No Information provided
	Romania	Finland	Austria
	Integration of smart meters into Building Energy Monitoring Systems (BEMS) forms the foundation of smartification initiatives. Proactive measures to address data security concerns underline commitment to technological advancement.	Sophisticated array of solutions for building automation and energy management, with challenges in seamless integration and interoperability. Emphasis on aligning technological advancements with existing infrastructure.	Availability of technological solutions for smart buildings, particularly in energy-related sectors. Challenges include interoperability between devices and data quality issues, necessitating ongoing integration efforts.

4.4.1 France

France's smart building sector is well-organized, represented by the Smart Building Alliance (SBA) with 450 member companies. This indicates a robust technological landscape. The development of the GOFLEX tool, claimed to be SRI-compatible, showcases the industry's commitment to advancing technological solutions for quantifying the flexibility potential of buildings. France's technological prowess in the smart building sector positions it favourably for further advancements and adoption.

More specifically, ENTECH's pilot case incorporates various smartification technologies, including controllable building assets, energy storage systems, renewable energy generation, and an Energy Management System. The technological landscape appears robust, with available market solutions. The company, specializing in complex energy systems, indicates a positive experience with these technologies, emphasizing their proficiency in utilizing and managing smart systems.

4.4.2 Spain

For the case of Spain, the inclusion of specifics such as Biomass Central Heating, PV systems, and sophisticated monitoring platforms provides a comprehensive understanding of the technological ecosystem.

The acknowledgment that technological solutions are readily available but not always easy to integrate resonates with the broader challenges faced in the technological dimension. This complexity is further exemplified by the detailed experience shared regarding the deployment of IoT solutions for energy monitoring. The stages of integration, from field equipment integration to collaboration with third-party information systems, provide a nuanced view of the intricacies involved in adopting and integrating smart technologies.

Furthermore, the mention of future developments, such as the setting up of battery energy systems and the expansion of monitoring, control, and operation through IoT devices, hints at a continuous technological evolution. This forward-looking perspective is crucial in navigating the rapidly advancing landscape of smart building technologies.

4.4.3 Romania

At the heart of the Romanian pilot case's foray into smart building technologies lies the integration of smart meters into the Building Energy Monitoring System (BEMS). This strategic approach, leveraging readily available technological solutions such as smart meters and PV systems, forms the bedrock of the smartification initiative.

The Building Energy Monitoring System (BEMS) has been operational since 2017, offering a user-friendly interface that facilitates ease of use. However, the implementation journey is not without its challenges. Acknowledging the paramount concern of data security, the initiative has taken proactive measures to address these apprehensions. This dual focus on technological advancement and security underscores a commitment to ensuring that the benefits of smartification are not compromised by potential vulnerabilities.

A notable challenge surfaces in the form of the slow implementation of smart meters and the existing state of the local grid infrastructure. The pilot case recognizes the crucial role of local grid infrastructure in supporting smart buildings, and it is evident that the current setup is not fully prepared for this technological

transition. To navigate this hurdle, collaboration with local partners becomes imperative. This collaborative approach seeks to ensure the seamless integration of smart technologies into the existing grid infrastructure, laying the groundwork for a more interconnected and efficient energy landscape.

In navigating the intersection of technology, security, and infrastructure, the pilot case embodies a dynamic and adaptive approach to smartification. By leveraging established technologies, addressing concerns, and actively engaging with local partners, the initiative charts a course towards a future where smart buildings seamlessly integrate with existing infrastructures, fostering a sustainable and technologically advanced built environment.

4.4.4 Finland

The technological landscape in Finland's pilot case showcases a sophisticated array of solutions employed for building automation and smartification. Advanced building automation systems, along with necessary actuators and sensors, are readily available in the market. The challenge often lies in seamless system integration, emphasizing the need for interoperability between solutions from different vendors. The chosen technologies, including air handling units, chillers, and automation control panels, reflect a comprehensive approach to building management.

While the technology is generally user-friendly, challenges during commissioning and configuration phases highlight the importance of a robust implementation process. The inclusion of local energy production through geothermal equipment and solar power, coupled with battery energy storage units, represents a holistic approach to energy management. The need for next-generation smart meters and grid infrastructure upgrades underlines the importance of aligning technological advancements with existing infrastructure for a seamless integration process.

4.4.5 Austria

For the Austrian pilot case a range of smartification technologies, including smart meters, local energy production, and sensors exist. The availability of technological solutions in the market for smart buildings is notable, especially in the context of energy-related solutions. Building Energy Management systems, addressing

devices like heat pumps, electric vehicle wall-boxes, and air conditioners, are already on the market.

However, challenges persist, primarily in the interoperability between devices and the lack of sophisticated control algorithms. The integration of smart meters into the electric grid infrastructure is underway, with a target of 95% integration by 2024. Data quality issues, such as missing data points and delays, highlight existing challenges.

4.5 Environmental

Buildings bear a substantial environmental footprint, contributing to approximately 40% of global emissions when considering both building materials and operating emissions [5]. Advancing the net-zero agenda becomes a key factor influencing real-estate decisions, prompting the need for technologies and strategies that support resilience and sustainable building practices.

Creating climate-smart cities involves a diverse array of measures tailored to specific location needs, ranging from flood defences and drainage canals to electrified transport and the integration of green spaces for urban cooling [16].

Designing buildings to be resilient to climate change impacts is crucial. Considerations such as round-shaped houses and optimal aerodynamic orientation can mitigate the strength of winds, showcasing a proactive approach to climate resilience. From reducing indoor heat in hot and arid regions to mitigating cyclone impacts in hot and humid climates, valuable insights for constructing resilient buildings and communities can be found in literature [17].

Temperature plays a pivotal role in various aspects of commercial buildings, influencing occupant comfort, productivity, and even energy efficiency. For industries such as food and hospitality, adherence to compliance standards is also contingent on maintaining specific temperature levels [18]. The advent of real-time temperature and location monitoring is transforming building temperature management, offering business owners simplified and automated solutions.

The significance of temperature control becomes even more pronounced as smart buildings emerge as a competitive consideration for modern businesses [18]. Remote temperature monitoring takes centre stage, emerging as a crucial dataset for efficient building management in this evolving landscape.

Moreover, understanding how geomorphology impacts the development of smart buildings involves considering various aspects. The suitability of a construction site, influenced by landforms and geological conditions, is a foundational factor, with research in geotechnical engineering offering insights [19]. Geomorphological features, like fault lines or flood-prone areas, can affect the resilience of buildings, including smart structures, requiring insights from natural hazard assessment studies. Local topography and climate, shaped by geomorphology, play a role in the energy efficiency of smart buildings, a consideration explored in sustainable architecture research.

Additionally, the integration of smart infrastructure and the adaptability of buildings to climate change are influenced by the specific geomorphological context, prompting a multidisciplinary approach involving geosciences, engineering, and architecture for a comprehensive understanding. While not explicitly addressed in one source, synthesizing information from diverse scientific studies provides a nuanced perspective on the relationship between geomorphology and smart building development [16].

Table 6 Environmental factors in the participating countries

PESTEL Dimensi on	France	Spain	Italy
Environ- mental	Balanced regulatory environment with focus on insulation performance and materials alongside integration of smart technologies. Certification schemes like Ready2Service emphasize digital performance and energy efficiency, aligning with broader environ-mental goals.	Integration of environ-mental regulations into smart building development, empha-sizing energy efficiency, renewables, and comfort. Adherence to standards like BREEAM, LEED, and VERDE underscores commitment to sustainable construction practices.	Compliance with EU directives like EPBD influences smart building design. Initiatives such as the ITACA Protocol and involvement with GBC Italia promote sustainability and energy efficiency. Environmental regulations play a crucial role in shaping smart building standards in Italy.
	Romania Emphasis on green building certifications like BREEAM and LEED, indicating a commitment to environmentally responsible construction practices. Integration of smart and sustainable technologies within the National Recovery and Resilience Plan reflects a	Finland Regulatory focus on energy efficiency with smart solutions used to achieve efficiency goals. Voluntary certifications like BREEAM and LEED provide benchmarks for environmental standards. Consideration of local climate conditions influences building design	Austria Impact of local environment and climate on building design and construction practices. Government initiatives promote sustainable building practices through tax credits and rebates. Alignment with EU sustainability assessment directives and ESG

	proactive approach to environmental sustainability on a national scale.	and construction practices.	principles underscores commitment to environmental sustainability.
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4.5.1 France

The existing environmental regulation (RE2020) primarily focuses on insulation performance and materials, not hindering or promoting smart aspects. Certification schemes like Ready2Service (R2S) and R2S-4GRIDS, offered by CERTIVEA, emphasize digital performance and energy efficiency, aligning with broader environmental goals. Overall, the regulatory environment provides a balanced approach, addressing both environmental concerns and the integration of smart technologies.

The pilot case in France reflects a conscious effort to align with environmental regulations and standards. The building's design adheres to ecological processes, obtaining Passivhaus certification for energy efficiency. Environmental regulations focus on energy efficiency and renewable energy integration. The Climate and Resilience Law mandates photovoltaic installations, emphasizing the environmental impact of smart buildings in France.

4.5.2 Spain

Spain's commitment to integrating environmental regulations into the development and implementation of smart buildings highlights is well established. The emphasis on energy efficiency, renewables, and comfort aligns with broader sustainability goals.

The explicit mention of standards such as BREEAM, LEED, and VERDE provides a tangible link between environmental regulations and smart building design. The incorporation of these standards underscores a commitment to not just meeting regulatory requirements but actively participating in a global discourse on environmentally conscious construction.

Moreover, the recognition of UNE standards promoting digitization and interoperability within the context of smart cities further solidifies the connection between environmental goals and technological advancements. This alignment

ensures that the development and operation of smart buildings adhere to not only national regulations but also international standards that prioritize sustainability.

4.5.3 Italy

Environmental regulations in Italy, notably the ITACA Protocol and involvement with GBC Italia, play a crucial role in shaping smart building standards. Compliance with EU directives like the EPBD influences the design and operation of smart buildings. The ITACA Protocol evaluates sustainability, encouraging technologies that enhance energy efficiency, water conservation, and overall environmental impact.

4.5.4 Romania

Romania has taken significant strides on the environmental front, aligning itself with global sustainability standards. Noteworthy among these efforts are initiatives like BREEAM and LEED certifications, which serve as benchmarks for green buildings. These certifications underscore the nation's commitment to fostering environmentally responsible construction practices.

The country's commitment to environmental resilience is further evident in the National Recovery and Resilience Plan. This comprehensive strategy places a strong emphasis on integrating smart and sustainable technologies, positioning Romania at the forefront of environmental initiatives on a national scale.

Looking ahead, a proactive green building evaluation, in collaboration with the Romanian Green Building Council, is on the horizon. This assessment underscores a commitment to thorough environmental considerations, ensuring that smart building technologies align with and contribute to broader sustainability objectives.

Crucially, the landscape appears favourable in terms of existing environmental regulations. The absence of significant barriers suggests a regulatory environment that is conducive to the integration of smart and sustainable technologies. This regulatory alignment not only facilitates the implementation of green building initiatives but also signifies a harmonious relationship between technological advancement and environmental responsibility.

In essence, Romania's approach to environmental considerations reflects a multifaceted commitment, encompassing certifications, national recovery plans,

proactive evaluations, and regulatory alignment. This comprehensive strategy positions the nation as a leader in fostering a built environment that not only embraces technological innovation but does so with a keen awareness of its environmental impact and a commitment to sustainable practices.

4.5.5 Finland

The environmental dimension of smart buildings in Finland is intricately tied to historical energy needs and evolving regulatory frameworks. Traditionally focused on heating, the inclusion of chillers in response to warmer summers illustrates a responsiveness to local climate conditions. The growth of wind energy and its impact on electrical energy prices add a layer of complexity to the environmental landscape.

Environmental regulations primarily target energy efficiency for new buildings, with smart solutions seen as a means to showcase and achieve efficiency goals. Voluntary certifications such as BREEAM and LEED, while not mandatory, provide a benchmark for environmental standards. The installation of geothermal heat pumps requires compliance with building permits, emphasizing a regulatory aspect tied to environmental impact assessment.

4.5.6 Austria

The local environment and climate significantly influence the development of smart buildings in Austria. Climate considerations impact the design and construction of buildings, influencing factors such as insulation, heating, ventilation, and materials used. The Austrian government has implemented initiatives, including tax credits and rebates, to promote sustainable building practices, further encouraging the development of smart buildings.

While there are no specific environmental standards for smart buildings, green building concepts are emphasized. The focus on renewable energy, sustainable materials, and intelligent building management aligns with the EU's sustainability assessment directives and ESG principles.

No environmental impact assessment study was required for the pilot case, emphasizing the ongoing alignment with existing environmental regulations.

4.6 Legal

A challenge that may be faced is the bureaucracy in the EU countries. Navigating complex regulations related to energy efficiency is not always easy, issues like data privacy, cybersecurity and data interoperability are raised [5].

Regarding data privacy, smart buildings rely heavily on data collection and data sharing. Data privacy and cyber security are crucial factors to be taken into consideration and are addressed by European Data Protection Laws:

- European General Data Protection Regulation (GDPR) [20], established in 2018 aims to address data protection and data privacy in smart buildings and smart cities.
- Network and Information Security Directive (“Cyber Security Directive” or NIS2) [21] aims to boost operational technology security, simplify reporting, and create consistent rules and penalties across the EU. NIS2’s goal is the enhancement of EU’s cyber security.

Organizations operating smart buildings must comply with local laws and regulations, implementing the Data Protection Directive (DP Directive). The same goes for subcontractors or suppliers processing personal data on behalf of data controllers, they are considered data processors and even though they do not have a direct obligation under the DP Directive at the time this report is written, that may change soon enough.

Some of the best practices for data privacy in smart buildings are data encryption and data anonymize personal data within smart devices and production/consumption patterns [13]. Another practice is to keep the data as close to the source as possible, reducing reliance on external servers and network access, in the case of BAUNs that may prove difficult.

Another challenge is taxation on smart buildings when used as BAUNs. Besides the tax implications BAUNs face when generating and selling energy on a national level, taxes may arise on a local and municipal level. On the same matter proper documentation and reporting are crucial, as “businesses” must keep track of the expenses related to smart building implementation.

Table 7 Legal factors in the participating countries

PESTEL Dimension	France	Spain	Italy
Legal	Recognition of collective self-consumption projects and smart grid initiatives with limited legal requirements for smart features. Compliance with GDPR for data privacy and the 'Décret BACS' mandate for non-residential tertiary buildings are notable legal aspects.	Legal recognition of self-consumers, energy communities, and data privacy laws under Organic Law 3/2018 and GDPR. The Technical Building Code (CTE) establishes legal mandates for smart features, reflecting a proactive approach to integrating technological advancements.	Formalization of concepts like prosumers and renewable energy communities in national legislation, defining configurations for renewable energy self-consumption groups. Legal frameworks such as Decree-Law 162/19 and Resolution 318/2020/R/eel foster the growth of these concepts.
	Romania	Finland	Austria
	Alignment with EU directives, accommodating prosumers, and smart buildings. However, a gap exists in addressing energy communities. Data privacy concerns are acknowledged, though specific legal frameworks are lacking. Legal requirements for smart features are integrated into the Buildings Energy Performance Law.	Recognition of prosumers and energy communities in national legislation, with a progressive policy framework for construction and energy efficiency. Adherence to GDPR for data privacy and a focus on energy efficiency in building codes shape the legal landscape for smart buildings.	Formal recognition of prosumers and energy communities in national legislation. Legal frameworks like the Federal Energy Efficiency Act and GDPR shape the landscape for smart buildings. Compliance with OIB Guideline 6 and building regulations ensures adherence to national and EU standards.

4.6.1 France

While France recognises collective self-consumption projects, the energy community concept is underdeveloped. Pilot smart grid projects at the district level receive support from various authorities, indicating a legal framework encouraging experimentation. Data privacy laws are addressed through the BDNB database and initiatives like the Carnet d'information du logement (CIL), focusing on content rather than digital format. Notably, legal requirements for incorporating smart features are limited, with the 'Décret BACS' being an exception for larger tertiary buildings.

France has recognised and formalised concepts like renewable energy communities and collective self-consumption. The legal framework, although not explicitly defining "smart buildings," accommodates the integration of active and passive energy management solutions. Data privacy laws, governed by the GDPR,

impact the collection, storage, and usage of data within smart buildings, emphasizing the importance of consent and security measures. The BACS decree sets a legal mandate for automation and control systems in non-residential tertiary buildings.

4.6.2 Spain

Spain's recognises key legal concepts related to smart buildings, such as self-consumers, energy communities, and independent aggregators. However, the need for further legal development to empower these entities fully indicates the evolving nature of legal frameworks in the smart building domain.

The exploration of data privacy laws, emphasizes the compliance with the Organic Law 3/2018 on Data Protection and Digital Rights Guarantee and the General Data Protection Regulation (GDPR) of the European Union. The specific obligations, including obtaining explicit consent, ensuring user rights, and implementing security measures, offer a granular understanding of the legal landscape surrounding data privacy within smart buildings.

The Technical Building Code (CTE) establishes the legal mandate for incorporating smart features in new constructions or retrofits. This not only positions smart buildings as a regulatory imperative but also underscores a proactive legal framework that anticipates the integration of technological advancements into construction practices.

4.6.3 Italy

Italy recognises and formalises concepts like prosumers and renewable energy communities in national legislation, enabling consumers to collectively produce and consume locally generated renewable energy. The legal framework, including Decree-Law 162/19, Resolution 318/2020/R/eel, and Ministerial Decree of September 16, 2020, defines configurations for renewable energy self-consumption groups and renewable energy communities, fostering the growth of these concepts.

4.6.4 Romania

In the legal realm, Romania has made considerable strides in aligning its framework with European Union directives, reflecting a commitment to staying at the forefront of regulatory standards. Notably, national laws have been crafted to

translate these directives into actionable provisions, with a specific focus on accommodating prosumers and the burgeoning domain of smart buildings.

While there is commendable progress in these areas, a noticeable gap exists in terms of initiatives related to energy communities. The legal landscape currently lacks significant measures to address the nuances and potential of energy communities, signalling an area for potential future exploration and development. Data privacy, a crucial aspect in the context of smart buildings, is yet to have a specific legal framework in Romania. Despite this, the legal landscape acknowledges the concerns surrounding data privacy. In response, the pilot case is proactively taking steps to ensure secure communication lines, showcasing a commitment to addressing potential challenges even in the absence of explicit legal guidance.

Building on this, legal requirements for smart features find their place within the Buildings Energy Performance Law. This integration demonstrates a forward-thinking approach, embedding the regulatory framework directly into the legislation governing building energy performance. These legal stipulations have a broad reach, impacting not only new constructions but also influencing retrofitting initiatives, ensuring a cohesive and standardized approach to the integration of smart features across the built environment.

4.6.5 Finland

Legally, Finland recognizes and formalizes concepts such as prosumers and energy communities. The national policy framework is progressively becoming more stringent in terms of construction and energy efficiency. Data privacy laws adhere to common European requirements, exemplified by the General Data Protection Regulation (GDPR). While there are no specific legal mandates for smartification, existing regulations promoting energy efficiency indirectly influence the incorporation of smart features in new constructions or retrofits.

The absence of direct legal requirements for smartification creates a space where voluntary certifications, including environmental standards like BREEAM and LEED, gain prominence. Building codes primarily emphasize energy efficiency, leaving room for innovation in smart solutions without imposing specific legal mandates.

4.6.6 Austria

Austria formally recognizes concepts like prosumers and energy communities in its national legislation. Legal frameworks, including the Federal Energy Efficiency Act, building regulations, and the GDPR, shape the landscape for smart buildings. The OIB Guideline 6, a critical element in implementing the EPBD, and building regulations at the federal and state levels are key components of the legal framework.

Data privacy laws, under the GDPR, impact the collection, storage, and usage of data within smart buildings. Compliance with legal frameworks is essential for smart features, ensuring adherence to national and EU regulations.

5 DISCUSSION

5.1 Synopsis

Smart buildings encompass advanced technologies and systems that optimize resource usage, enhance occupant comfort, and facilitate efficient operation and management. Integrating smart building features in line with smart city infrastructure domains necessitates designing buildings to foster seamless interaction with existing and evolving city infrastructure [22]. Collaborative approaches that involve professionals from various fields, such as scientists, policymakers, planners, managers, civil society representatives, and other relevant stakeholders, prove beneficial and effective in achieving this integration.

The transformation of smart buildings into active utility nodes in **Spain** and **Italy** faces several **legal and technological** barriers and drivers. The last years, **Italian** national energy policies have undergone significant changes with the introduction of new laws, regulatory measures, and technical methodologies [23]. These changes aim to encourage more reasonable energy consumption and the generation of Renewable Energy Sources (RESs). Despite these advancements, some implementation responsibilities are delegated to local or regional authorities, leading to a lack of uniformity in information regarding energy efficiency strategies [24]. To address this issue, it is crucial to establish stricter controls to verify the accuracy of the data declared and established across various regions.

The legal status of smart buildings and active utility nodes in **Spain** is shaped by a mix of national and regional legislation, regulatory frameworks, and technical standards. These instruments aim to promote energy efficiency, reduce energy consumption, and integrate renewable energy sources in the built environment.

Both Spain and Italy have their unique legal frameworks that influence the transformation of smart buildings. These laws set goals for energy efficiency, renewable energy, and carbon emissions reduction, which indirectly contribute to the transformation of smart buildings into active utility nodes. It is also important to have in mind that when implementing data-driven energy management systems and sharing data between buildings and the grid the countries need to ensure compliance with the respective laws.

France has a well-established **legal framework** for energy transition and renewable energy sources. The French Energy Transition for Green Growth law

(2015) aims to reduce greenhouse gas emissions and promote energy efficiency. This law encourages the development of smart buildings and active utility nodes. Both France and **Austria** have a favorable legal framework, regulatory support, and technological advancements that can drive the transformation of smart buildings into active utility nodes. Financial incentives and funding programs in both countries also contribute to this transition. However, addressing the technological barriers, such as interoperability and standardization issues, will be crucial for the successful implementation of active utility nodes in smart buildings.

In **France**, the limited **public awareness** about smart building technologies and their benefits necessitates increased education and awareness campaigns. Addressing concerns about smart metering, data privacy, and potential health impacts can help drive public acceptance. Legislative changes and awareness initiatives can play a significant role in improving understanding and acceptance. Meanwhile, in **Austria**, public awareness in relation to smart buildings is evolving, with notable interest from younger generations. Data privacy and security concerns are pronounced, especially among older demographics. Community engagement is crucial for shaping social interactions and addressing public concerns. At the same position lays **Spain** where there is **positive societal** inclination towards sustainability, which can be leveraged to promote smart building technologies. However, a cautious approach towards data privacy is evident in the public mindset. The property ownership structure influences decision-making processes, and robust privacy measures are essential for widespread acceptance.

In **Romania**, also public acceptance faces challenges due to factors like delayed technology adoption, perceived high costs, and data security concerns. On the other hand, the last years the engagement of students shows promise, but broader acceptance remains a gap. Addressing data security concerns is crucial for fostering public trust and acceptance. Overall, in all the countries addressed in this deliverable, the new technology-related risk is generally known to be one of the barriers of smartness in building, especially when it comes to social aspects.

According to Ibanescu et al. [25], the last years, Romania saw a great evolution in the development of smart building sector. However, only a few of the projects are operational and not all of them have an impact on the local economy, society, or

technological development. Another barrier seems to be the lack of a reporting system to assess the sustainability of these projects.

Regarding the **technological factors**, in **Finland**, there is a diverse range of solutions for building automation and energy management. However, challenges exist in ensuring seamless integration and interoperability among these technologies. Aligning technological advancements with existing infrastructure is crucial for the successful transformation of buildings into BAUNs. At this point, it needs to be mentioned that as far as the combination of legal/ policy perspective and technology is concerned, the Smart Readiness Indicator (SRI) that is receiving a lot of attention has to be re-assessed as its baseline design is not feasible for buildings in cold climate countries [26]. In any case, the political commitment in Finland is in line with the European standards regarding the adoption of smart solutions for energy efficiency and sustainability.

The same is applicable for **Austria**, which boasts a **variety of technological solutions**, particularly in energy-related sectors for smart buildings. The primary challenges involve achieving interoperability between devices and maintaining data quality, which requires continuous integration efforts.

France has a **strong technological landscape**, with organisations like the Smart Building Alliance driving innovation. Advanced tools, such as the GOFLEX tool, demonstrate a commitment to technological advancements in the smart building sector.

Denmark is leading the way in smart building technology, with a strong focus on energy efficiency and sustainability, and a goal of Copenhagen becoming the first carbon-neutral capital by 2025. The country's buildings account for up to 40% of total energy demand, making this sector crucial in the green transition. There is concerted effort to create smart buildings that offer more flexibility, comfort, and energy efficiency [27], [28]. However, transitioning from traditional building practices to the smart building market poses challenges. These include the **need for open collaboration, information and risk sharing**, and **self-investment**. Despite these challenges, Denmark's commitment to **research and development, robust service sector**, and **low inequality rates** provide a conducive environment for the growth and development of smart buildings [29].

Finally, for the case of **Greece**, smart buildings are gaining traction over the past few years, with **energy efficiency being a key focus**, as highlighted in the Greek

NECP. However, the implementation of energy efficiency measures faces challenges such as a **lack of capital, high costs**, and the impact of the **2019 pandemic** [30]. Despite recent advancements, such as the development of The Ellinikon project [31], Greece's smart building sector still faces significant challenges. The country's political instability, economic difficulties, and the **slow pace of digital transformation** among small and medium-sized enterprises could hinder the growth of this sector [32]. Nevertheless, with concerted efforts in the areas of policy and investments, Greece has the potential to overcome these challenges and become a key player in the smart building industry.

As mentioned, **EU** developed the SRI to assess the **technological readiness** of buildings based on their capabilities to interact with their occupants and the energy grids and to provide more efficient operation [33]. However, there is a limitation to the use of SRI that is the lack of numerical evaluation of the amount of energy reduction that can be obtained. This can be perceived a barrier that might discourage stakeholders that would like to invest as they don't have an indication of the final performance of the building [34].

5.2 Outlook/Update

The activities performed in the first part of Task 1.1 were to define the factors that are influencing or hinder the conversion of smart buildings into BAUNs and their integration in a smart city. The assessment was made at EU level and at national level from the partners that participate in this Task.

The second part of the activities will focus more on the use cases of the pilot sites as they will be defined during the progress of EVELIXIA project. In the meantime, the stakeholders will be more concretely described. This will provide deeper knowledge of the pilots and through a participatory workshop we will apply a SWOT analysis to develop recommendations and strategies that will help them frame the situation.

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7 APPENDIX I PESTEL RESULTS

PESTEL Dimension	France	Spain	Italy	Romania	Finland	Austria
Political	Proactive alignment with EU directives, particularly EPBD, showcasing commitment to energy performance improvement. Collaboration between government, industry players, and initiatives like 'Ready to services' label, 'NF Habitat HQE' certification.	Alignment with EU directives such as EED and EPBD, reflected in the integration of EPBD into the Technical Building Code. Focus on self-consumption regulations with adaptability challenges indicating the need for further regulatory refinement.	Successful transposition of EU directives into national law with standards like UNI EN ISO 5120-1 and policy schemes supporting smart buildings. Implementation of mandatory automation levels in new constructions and funding initiatives like 'Superbonus 110%' driving smart building development.	Legislative amendments emphasizing smart buildings, supported by measures to encourage prosumers and foster sustainable energy landscapes. Inclusion of smart building technologies within strategic initiatives like the National Recovery and Resilience Plan for environmental sustainability.	Active participation in EU initiatives like SRI with pending decisions on mandatory vs. voluntary adoption, reflecting a nuanced regulatory approach. Political commitment to adopting smart solutions for enhancing energy efficiency and sustainability in line with European standards.	Strong alignment with EU directives like EPBD and NZEB targets, managed through institutions like the Austrian Institute of Construction Engineering. Implementation of Digital Action Plan and Digital Austria initiative supporting digitization and fostering competitiveness and innovation.
Economic	Implementation of economic incentives like 'Décret BACS' for building automation. Commitment to smart meter rollout and demand response mechanisms. Lack of direct incentive schemes for smart buildings.	Integration of smart building initiatives within broader legal frameworks like Ley 10/2022. Emphasis on rehabilitation activities and digitalization of buildings. Nuanced economic incentives including grants for rehabilitation and renewable energy.	Preemptive economic approach with incentives linked to energy efficiency legislation. Tax incentives like 'Superbonus 110%' driving smart building adoption. Legislative support for renewable energy communities contributing indirectly to smart building development.	Suite of financial incentives including Regional Operational Program and Modernisation Fund. Allocation of funds within National Recovery and Resilience Plan for smart building projects. Rigorous cost-benefit analysis to assess economic feasibility.	Reliance on existing support schemes for energy efficiency improvements. Consideration of local energy dynamics like electricity prices and climatic conditions. Focus on long-term energy savings rather than direct financial incentives.	Multifaceted economic considerations including costs, energy savings, and market demand. Federal and regional funding programs supporting smart building adoption. Ongoing pilot case influenced by economic feasibility and potential revenue opportunities.
Social	Limited public awareness necessitates increased education and awareness campaigns. Concerns about smart metering, data privacy, and health impact public acceptance. Legislative changes and awareness initiatives are expected to drive public	Positive societal inclination towards sustainability but cautious approach towards data privacy. Social dynamics vary based on property ownership structure, influencing decision-making processes. Robust privacy measures are essential	No information provided	Challenges in public acceptance due to factors like delay in technology adoption, perceived high costs, and data security concerns. Engagement efforts with students show promise but broader acceptance remains a gap.	Limited public awareness necessitates broader education on long-term benefits. Privacy and security concerns are focal points, requiring proactive measures. Social dynamics of residents influence system adoption, highlighting the	Evolving public awareness with notable interest from younger generations. Concerns about data privacy and security are pronounced, especially among older demographics. Community engagement is crucial for shaping social interactions and addressing public concerns.

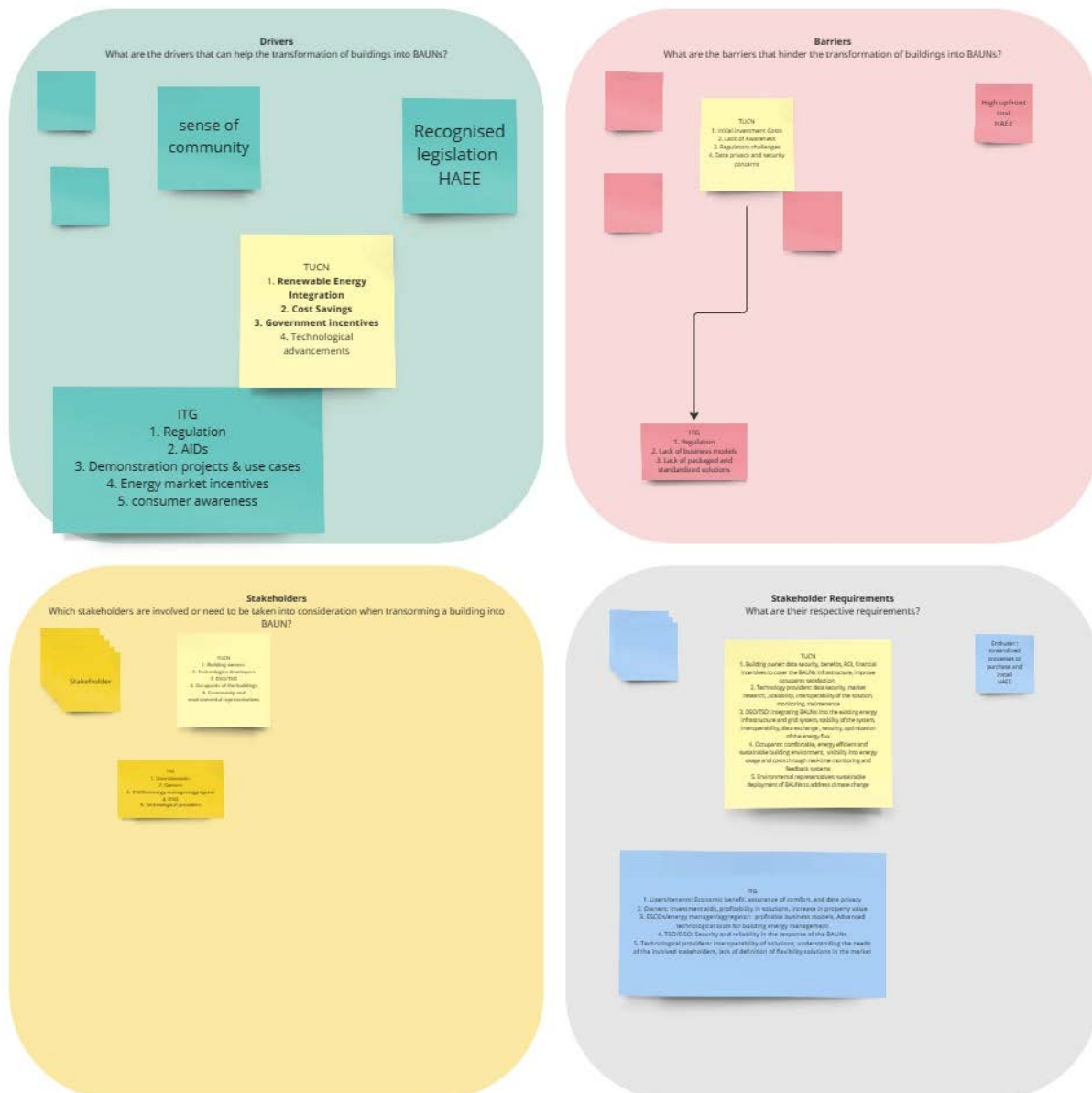
	understanding and acceptance.	for widespread public acceptance of smart building technologies.		Addressing data security concerns is crucial for fostering public trust and acceptance.	importance of ease of use and comfort in smart building design.	
Technological	Robust technological landscape represented by organizations like the Smart Building Alliance. Advanced tools like the GOFLEX tool demonstrate commitment to technological advancements.	Availability of diverse technological solutions for smart buildings, although integration complexities exist. Forward-looking perspective towards continuous technological evolution.	No information provided	Integration of smart meters into Building Energy Monitoring Systems (BEMS) forms the foundation of smartification initiatives. Proactive measures to address data security concerns underline commitment to technological advancement.	Sophisticated array of solutions for building automation and energy management, with challenges in seamless integration and interoperability. Emphasis on aligning technological advancements with existing infrastructure.	Availability of technological solutions for smart buildings, particularly in energy-related sectors. Challenges include interoperability between devices and data quality issues, necessitating ongoing integration efforts.
Environmental	Balanced regulatory environment with focus on insulation performance and materials alongside integration of smart technologies. Certification schemes like Ready2Service emphasize digital performance and energy efficiency, aligning with broader environmental goals.	Integration of environmental regulations into smart building development, emphasizing energy efficiency, renewables, and comfort. Adherence to standards like BREEAM, LEED, and VERDE underscores commitment to sustainable construction practices.	Compliance with EU directives like EPBD influences smart building design. Initiatives such as the ITACA Protocol and involvement with GBC Italia promote sustainability and energy efficiency. Environmental regulations play a crucial role in shaping smart building standards in Italy.	Emphasis on green building certifications like BREEAM and LEED, indicating a commitment to environmentally responsible construction practices. Integration of smart and sustainable technologies within the National Recovery and Resilience Plan reflects a proactive approach to environmental sustainability on a national scale.	Regulatory focus on energy efficiency with smart solutions used to achieve efficiency goals. Voluntary certifications like BREEAM and LEED provide benchmarks for environmental standards. Consideration of local climate conditions influences building design and construction practices.	Impact of local environment and climate on building design and construction practices. Government initiatives promote sustainable building practices through tax credits and rebates. Alignment with EU sustainability assessment directives and ESG principles underscores commitment to environmental sustainability.

Legal	Recognition of collective self-consumption projects and smart grid initiatives with limited legal requirements for smart features. Compliance with GDPR for data privacy and the 'Décret BACS' mandate for non-residential tertiary buildings are notable legal aspects.	Legal recognition of self-consumers, energy communities, and data privacy laws under Organic Law 3/2018 and GDPR. The Technical Building Code (CTE) establishes legal mandates for smart features, reflecting a proactive approach to integrating technological advancements.	Formalization of concepts like prosumers and renewable energy communities in national legislation, defining configurations for renewable energy self-consumption groups. Legal frameworks such as Decree-Law 162/19 and Resolution 318/2020/R/eel foster the growth of these concepts.	Alignment with EU directives, accommodating prosumers and smart buildings. However, a gap exists in addressing energy communities. Data privacy concerns are acknowledged, though specific legal frameworks are lacking. Legal requirements for smart features are integrated into the Buildings Energy Performance Law.	Recognition of prosumers and energy communities in national legislation, with a progressive policy framework for construction and energy efficiency. Adherence to GDPR for data privacy and a focus on energy efficiency in building codes shape the legal landscape for smart buildings.	Formal recognition of prosumers and energy communities in national legislation. Legal frameworks like the Federal Energy Efficiency Act and GDPR shape the landscape for smart buildings. Compliance with OIB Guideline 6 and building regulations ensures adherence to national and EU standards.
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8 APPENDIX II MIRO BOARDS

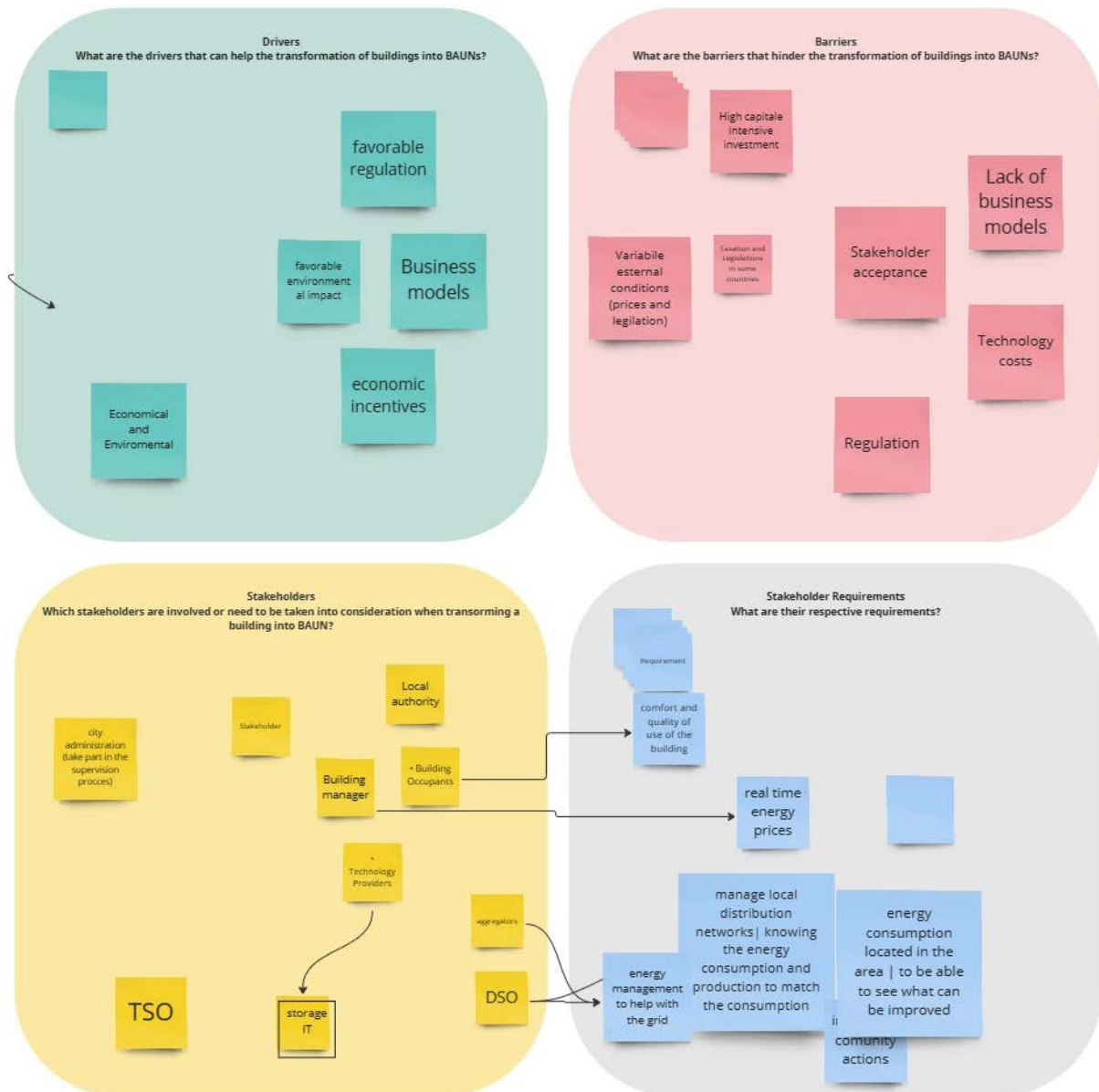
ROOM 1

1. EVELIXIA_Task 1.1 workshop_Feb2024



ROOM 2

1. EVELIXIA_Task 1.1 workshop_Feb2024



ROOM 3

1. EVELIXIA_Task 1.1 workshop_Feb2024

