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EXCESS

Flexible user-Centric Energy Positive Houses

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Policy Roadmap for deploying the PEB concept in the EU

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Abstract

This document provides a Policy Roadmap, including possible policy strategies, and instruments building on local to European strategies and processes that are favourable and supportive to Positive Energy Buildings (PEB) concepts. Important local planning processes like Sustainable Energy and Climate Action Plans are also addressed. Contextual factors, including rural and urban settings, newly constructed and existing building stock, various climatic conditions, etc. that affect the potential to upscale the EXCESS PEB concepts, have been included in the Policy Roadmap. For this, a database has been set up, spanning various contextual scenarios. All these elements have been considered in the elaboration of this Policy Roadmap aimed at providing national/regional and local authorities with guidelines for the transition from the current construction model to a sustainable one, in economic, social and environmental terms.

Keywords

Policy, incentives, business models, training, legislation.

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More information available at www.positive-energy-buildings.eu

Copyright Statement

Executive Summary.

In energy terms, the building sector represents the main energy consumption sector in the European Union, so, from an environmental protection perspective, it is urgent to take measures aimed at reducing energy consumption in the European building stock.

Both the construction and refurbishment of buildings in Europe needs to promote new models of **sustainable construction** oriented towards a Positive Energy Buildings (PEBs) given their multiple advantages at environmental, economic, and social cohesion level.

The promotion of PEBs from a building, district, city and regional level should be conceived as one of the pillars on which a new, more sustainable construction model is based, aligned with the objectives of the European directives on energy efficiency, renewable energy and waste treatment.

The PEBs also open the door to the constitution of new legal forms linked to sharing-surplus energy, which can be enjoyed by other citizens beyond the building itself, this **being the origin of new energy communities**.

The PEBs should also promote the **public and democratic character of cities** in their built enviroment and in the public space, improving the existing city, its accessibility and facilitating integration processes, avoiding the relocation of citizens and consolidating urban areas.

The Policy Roadmap has been elaborated to facilitate the upscaling and replication of PEBs concepts, providing national/regional and local authorities with guidelines for the transition from the current construction model to a sustainable one, in economic, social and environmental terms.

The actions proposed in this Roadmap attempt to address the main barriers, through concrete measures whose formulation has been made possible thanks to the knowledge gained from the studies carried out in the different work packages throughout the EXCESS project and the 4 demo sites implemented, as important testbeds for different analyses.

Thus, as a first step, the feasibility of different technologies that make a positive energy building focusing on the four demonstration sites and different climate zones of the EXCESS project, to subsequently evaluate the applicability of these solutions in other climatic zones, highlighting the importance of tailored made solutions, has been evaluated.

Executive Summary.

In the same way, the results of the analysis of the different energy efficiency schemes will also serve as a basis for public decision-makers to determine the most appropriate financial instruments to promote PEBs, in line with the need to promote new financial instruments and support for PEBs actions. In addition, a complete business opportunities analysis has been carried out based on the assessment of the broader market and regulatory context, allowing embedding the EXCESS project solutions into a broader context in order to integrate all available market opportunities.

Contextual factors, including rural and urban settings, newly constructed and existing building stock, various climatic conditions, etc. that affect the potential to upscale the EXCESS PEB concepts, have been also conducted in the Policy Roadmap. For this, a building stock database was therefore set up as an important tool for both upscaling and replication as it could help policy makers, investors, planners, developers, and other relevant stakeholders in making informed decisions about positive energy buildings.

In EXCESS, relevant work has already been carried out: a series of PEBs case studies have been developed at the beginning of the project and through this work a lot of information has been gathered to identify PEBs in different geographical locations. Aggregated analysis of these data has been conducted to show recurrent patterns across different PEBs.

The successful realisation of PEB projects requires the participation of many different stakeholders from early phases of the project in order to manage complexity, respond to needs and address requirements from different perspectives.

The inclusion of a wide variety of stakeholders is also a crucial element for developing strategies or regulations that support the implementation of PEBs. Also, end users need to be encouraged or rewarded for a correct energy use. It is important to raise the awareness of all stakeholders and to educate them on all energy efficiency and local RES integration.

Specifically, PEBs actions included in the Policy Roadmap aim to respond to the needs arising from the population sector with fewer resources and at risk of social exclusion. Promoting social inclusion and the fight against inequalities and poverty that affect these communities necessarily involves betting on the physical, social, economic and environmental regeneration of their residence environment.

Executive Summary.

Therefore, the present Policy Roadmap also aims to strengthen the concept of PEBs as guarantor of the social function of housing, combining the interests of owners, companies, building managers and technicians, financial institutions and public administrations, and facilitating access to decent housing for vulnerable groups.

With all the elements, the Policy Roadmap has been elaborated including measures associated with regulatory, financial, economic and social factors that have been discussed with EXCESS project partners and with the External Advisory Board (EAB) in different meetings. The EAB has allow to EXCESS project to establish and develop a permanent community of experts across Europe who has supported the project's successful completion, steer its development, and maximise its impact.

The strategic lines and axes of intervention are described in chapter seven. They are focused on providing national/regional and local authorities with guidelines for the transition from the current construction model to a sustainable one, in economic, social and environmental terms.

This Policy Roadmap details concrete steps to foster PEBs development to increase renewable energy generation, improve energy efficiency and decarbonise building stock in local and regional authorities' policy and planning documents in Europe.

List of abbreviations.

BEMS: Building Energy Management System

BiPV: Bifacial Photovoltaic Panel

CAPEX: Capital Expenditures

DEEP: De-risk Energy Efficiency Platform

GVA: Gross Value Added

GIS: Geographic Information System

EAB: External Advisory Board

EED: Energy Efficiency Directive

EPDB: Energy Performance Directive

ESCO: Energy Service Company

EV: Electric Vehicle

HVAC: Heating, Ventilation, and Air Conditioning

HEM: Home Energy Management System

KPI: Key Performance Indicator

ICT: Information and communication technology

LCA: Life-cycle assessment

LCOE: Levelled Cost of Energy

LG: Local Goverment

MS: Member State

NZEB: Nearly zero-emission building

OPEX: Operating Expenditures

OSS: One Stop Shop

PEB: Positive Energy Buildings

PEDs: Positive Energy Districts

PV: Photovoltaic materials and devices convert sunlight into electrical energy

PVT: photovoltaic thermal hybrid solar collector

RES: Renewable Energies

SEAPs/SECAPs: Sustainable Energy (and Climate) Action Plans

SWOT: Strengths, Weaknesses, Opportunities and Threats

ZEB: zero-emission building

WLC: Whole Life-Cycle Carbon emissions

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1.Introduction.

The construction sector in Europe is one of the sectors that, in economic and employment terms, has the most significant impact, representing 5,5 % of Gross Added Value (GVA) and 4 % of employment.

In energy terms, the building sector represents the main energy consumption sector in the European Union, so, from an environmental protection perspective, it is urgent to take measures aimed at reducing energy consumption in the European building stock.

Both the construction and refurbishment of buildings in Europe needs to promote new models of **sustainable construction** oriented towards a Positive Energy Buildings (PEBs) given their multiple advantages at environmental, economic, and social cohesion level.

The **environment** benefits from PEBs, through energy savings and efficiency, the incorporation of renewable energies, the rationalisation of the resources used, and the reduction of waste generated in the construction process. In **economic terms**, the promotion of PEBs is an element of **economic revival**, through the reorientation of the model towards more efficient and competitive structures, and the **generation of quality employment**.

In addition to the environmental benefits, **the social advantages associated with PEBs** should not be overlooked, since families will be able to reduce their energy bills by implementing measures to rationalise energy expenditure, which, in the case of disadvantaged groups, is an appropriate alternative to address the problems arising from **energy poverty**. The energy-saving potential of buildings (up to 70% in older and lower-quality houses should be recognised as a strategically optimal element to mitigate the adverse situation faced by many European families in dealing with their energy bills.

The measures to promote PEBs should therefore address the needs of the population as a matter of priority, leading to **the reduction of inequalities** between different groups, and providing a housing service as fair as possible for all citizens.

The PEBs also open the door to the constitution of new legal forms linked to sharing-surplus energy, which can be enjoyed by other citizens beyond the building itself, this **being the origin of new energy communities**.

Introduction.

The PEBs should also promote the **public and democratic character of cities** in their built enviroment and in the public space, improving the existing city, its accessibility and facilitating integration processes, avoiding the relocation of citizens and consolidating urban areas.

It is therefore a question of promoting a model through PEBs that combines the common interests of reducing energy use, the necessary environmental protection, a more efficient urban development, social cohesion, as well as the participation of all parties involved: citizens, companies and entities in the energy, construction, ICT, and financial sectors.

These approaches align with the strategic path marked by the **European Commission**, which conceives sustainability in construction as a dynamic process for the development of new solutions, involving investors, the construction industry, professionals, industry suppliers and other stakeholders in achieving sustainable development, considering the environment, energy, socio-economic and cultural issues.

While PEB solutions can be applied to both new and existing buildings, special attention should be given to solutions linked to the **renovation of existing buildings**, given their beneficial effects on quality job creation (three times more than new construction), on the environment, on rational land use and on the liveability of existing buildings, revitalising public space, improving existing cities and ultimately strengthening social cohesion in Europe, without increasing energy costs and improving energy efficiency.

Europe and its regions must champion a clear **opportunity for a smart specialisation** within the framework of European policies and for the development of actions linked to PEBs. Opportunities and actions that will reduce the energy consumption of buildings, the incorporation of energy efficient equipment and facilities, as well as the development of tools associated with innovative services in the implementation of these improvements.

Introduction.

To this end, it is urgent to involve a greater number of people and organisations in their development, which will result in greater transparency and greater responsibility of all participants, professionals, civil society, and companies linked to construction, which must be fundamental vectors for the change of model.

Special attention will be paid to the development of innovative sustainable construction measures aimed at social and low-income housing, as well as comprehensive actions in neighbourhoods and districts, and particularly those vulnerable groups where the reduction of energy expenditure can have a greater impact. It is therefore a question of finding suitable solutions for each profile, extending the benefits of sustainable construction to the whole of society.

All these elements have been considered in the elaboration of this Policy Roadmap aimed at providing **national/regional and local authorities** with guidelines for the transition from the current construction model to a sustainable one, in economic, social and environmental terms.

2.Methodology.

This Policy Roadmap has been developed to facilitate the upscaling and replication of PEBs concepts, providing national/regional and local authorities with guidelines for the transition from the current construction model to a sustainable one, in economic, social and environmental terms.

As part of the methodology for the elaboration of this document, a logical process has been followed, starting with the definition and scope suggested by the EXCESS project for Positive Energy Buildings (see chapter 4 of this report), followed by the identification and analysis of the main barriers in technical, economic, regulatory and social terms.

The proposals developed in this Roadmap attempt to address these barriers, through concrete measures whose formulation has been made possible thanks to the knowledge gained from the studies carried out in the different work packages throughout the EXCESS project and the 4 demo sites implemented, as important testbeds for different analyses.

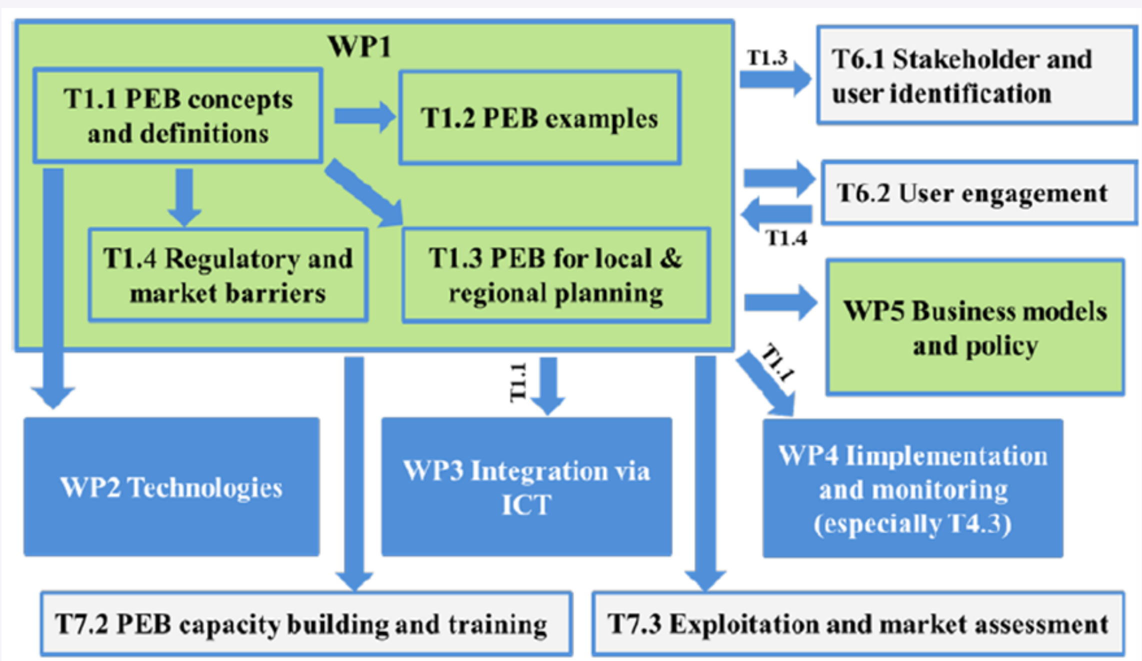


FIGURE 1: WPs and tasks in EXCESS

Methodology.

To do this, as a first step, the feasibility of different technologies that make a positive energy building focusing on the four demonstration sites and different climate zones of the EXCESS project, to subsequently evaluate the applicability of these solutions in other climatic zones, highlighting the importance of tailored made solutions, has been evaluated.

This approach ensures that the benefits of energy efficiency solutions are maximised but it adds a level of complexity when dealing with upscaling and replication. Key questions for replication include identifying suitable climate zones and building types, regulatory support, social dimensions, business models, financing, and competition with conventional technologies. These factors are crucial for adapting and scaling up EXCESS technologies in different regions. For instance, the 600m deep boreholes of the Finnish demo, could they be replicated elsewhere in Europe? Looking at building characteristics and features, could the multifunctional PV facade implemented in Austria be replicated in other buildings with small(er) surface available?

In this sense, it is worth highlighting among the results of the EXCESS project those related to the cost-optimal solution in PEBs analysis, whose results will help policy makers to identify the best technologies that make a positive energy building depending on the climate zone to which it belongs, in line with the need to improving the knowledge of PEBs by local decision-makers.

In the same way, the results of the analysis of the different energy efficiency schemes will also serve as a basis for public decision-makers to determine the most appropriate financial instruments to promote PEBs, in line with the need to promote new financial instruments and support for PEBs actions.

In addition, a complete business opportunities analysis has been carried out based on the assessment of the broader market and regulatory context, allowing embedding the EXCESS project solutions into a broader context in order to integrate all available market opportunities. For these business cases for PEBs, it has been necessary to identify the optimal costs of combinations of EXCESS technologies in different buildings stock and climate conditions and the analysis of the existing energy efficiency schemes.

Methodology.

A set of generic, replicable business models have been defined in the EXCESS project, each addressing specific technical elements as well as actors in the value chain. Based on implementation experiences, factors that facilitate specific business models have been identified. Boosting new business models is critical for the development of PEBs. The results of the business model developed has been an important input for an adequate seizing of the policy measures included in this Policy Roadmap.

A building stock database was therefore an important tool for both upscaling and replication as it could help policy makers, investors, planners, developers, and other relevant stakeholders in making informed decisions about positive energy buildings. In EXCESS, relevant work has already been carried out: a series of PEBs case studies have been developed at the beginning of the project and through this work a lot of information has been gathered to identify PEBs in different geographical locations. Aggregated analysis of these data has been conducted to show recurrent patterns across different PEBs. More information about other building database can be found in Annex 5.

This Policy Roadmap is complemented by other measures associated with regulatory, financial, economic and social factors that have been discussed with EXCESS project partners and with the External Advisory Board (EAB) in different meetings. The EAB had the aim to establish and develop a community of experts who can support the project's successful completion, steer its development, and maximise its impact.

Thus, after the first online meeting in February 2021, the second EAB meeting, on 21 and 22 March 2023 held in Helsinki, gathered 13 experts from four different climate zones to join the discussion on the EXCESS Policy Roadmap. During the third EAB meeting, which took place on 24 and 25 April 2024 in Valladolid, the progress made in the Policy Roadmap was presented to 12 EAB experts to further discuss on the expected results. This group brought together utility companies, academics, energy experts, architects, construction professionals and developers, investors, and local authorities.

Former industrial complex in Graz, Austria (Continental climate)

3. Legal Framework in Europe.

Buildings are responsible for approximately 40% of EU energy consumption and 36% of the energy-related greenhouse gas emissions. Buildings are therefore the greatest single energy consumer in Europe. Heating, cooling and domestic hot water account for 80% of the energy that we, the citizens, consume.

At present, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient. At the same time, only about 1% of the building stock is renewed each year.

The building sector is crucial for achieving the EU's energy and environmental goals. At the same time, better and more energy efficient buildings will improve the quality of citizens' life and alleviate energy poverty while bringing additional benefits, such as health and better indoor comfort levels, green jobs, to the economy and the society.

The EU Green Deal, aiming for Europe to become the first climate-neutral continent by 2050, was unveiled on 9 December 2019 as a growth strategy or a roadmap for achieving a sustainable European economy. Unlike the Clean Planet for All strategy, the EU Green Deal goes beyond climate and energy issues and addresses broader sustainability aspects such as reducing environmental pollution, protecting biodiversity and using resources efficiently.

More specifically, it touches upon the following policy areas: clean energy, sustainable industry, buildings and renovation, sustainable mobility, biodiversity, agriculture, pollution elimination and climate action. The EU Green Deal will consistently use all policy mechanisms to deliver this transformation: sectoral strategies and plans, regulations and standards, investments and innovations, national reforms, stakeholder dialogues and international cooperation. Renovating both public and private buildings was singled out in the European Green Deal as a key initiative to drive energy efficiency in the sector and deliver on objectives.

Previously, to boost energy performance of buildings, the EU had established a legislative framework that includes the Energy Performance of Buildings Directive 2010/31/EU and the Energy Efficiency Directive 2012/27/EU.

Legal Framework in Europe.

Together, the directives promote policies that will help:

- achieve a highly energy efficient and decarbonised building stock by 2050.
- create a stable environment for investment decisions.
- enable consumers and businesses to make more informed choices to save energy and money.

Both directives were amended in 2018 and 2019, as part of the Clean Energy for all Europeans Package and further updated till today.

Following the introduction of energy performance rules in national building codes, buildings consume only half as much today, compared to typical buildings from the 1980s.

The Directive amending the Energy Performance of Buildings (EPDB), Directive (2018/844/EU), introduced new elements and sent a strong political signal on the EU's commitment to modernise the buildings sector considering technological improvements and to increase building renovations. The EPBD was updated again in April 2024.

In October 2020, the Commission presented its Renovation Wave Strategy, as part of the European Green Deal. It contains an action plan with concrete regulatory, financing and enabling measures to boost building renovation. Its objective is to at least double the annual energy renovation rate of buildings by 2030 and to foster deep renovation, capturing the full potential of a building to reduce its energy demand, based on its typology and climatic zone. A revision of the Energy Performance of Buildings Directive was one of its key initiatives.

To make sure that buildings are fit for the enhanced climate ambition, as presented in the 2030 Climate Target Plan, and reflected in the "Delivering the European Green Deal Package" in July 2021, the Commission's new proposal aims to contribute to reaching the target of at least 60% emission reductions by 2030 in the building sector in comparison to 2015 and achieve climate neutrality by 2050. It should work hand in hand with other initiatives of the European Green Deal package with the review of the proposed new emissions trading system for fuels used in buildings, the Energy Efficiency Directive, the Renewable Energy Directive, as well as the Alternative Fuels Infrastructure Regulation.

The main measures in the new proposal are:

- the gradual introduction of minimum energy performance standards to trigger renovation of the worst performing buildings.

Legal Framework in Europe.

- a new standard for new buildings and a more ambitious vision for buildings to be zero-emission.
- enhanced long-term renovation strategies, to be renamed national Building Renovation Plans.
- increased reliability, quality and digitalisation of Energy Performance Certificates; with energy performance classes to be based on common criteria.
- a definition of deep renovation and the introduction of building renovation passports.
- modernisation of buildings and their systems, and better energy system integration (for heating, cooling, ventilation, charging of electric vehicles, renewable energy).

Following the proposals set out in July 2021, in December 2021, the Commission proposed a revision of the Energy Performance of Buildings Directive (COM(2021) 802 final). It upgrades the existing regulatory framework to reflect higher ambitions and more pressing needs in climate and social action, while providing EU countries with the flexibility needed to consider the differences in the building stock across Europe.

It also sets out how Europe can achieve a zero-emission and fully decarbonised building stock by 2050. The proposed measures were oriented to increase the rate of renovation, particularly for the worst-performing buildings in each country. According to this document, the revised directive should modernise the building stock, making it more resilient and accessible. It should also support better air quality, the digitalisation of energy systems for buildings and the roll-out of infrastructure for sustainable mobility. Crucially, the revised directive should facilitate more targeted financing to investments in the building sector, complementing other EU instruments supporting vulnerable consumers and fighting energy poverty.

As mentioned before, the EU also proposes to move from the current nearly zero-energy buildings to zero-emission buildings by 2030.

Nearly zero-emission building (NZEB) means a building that has a very high energy performance, while the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

Legal Framework in Europe.

The Commission's proposal to revise the directive makes a step forward from current NZEB to zero-emission building (ZEB), aligning the energy performance requirement for new buildings to the longer-term climate neutrality goal and "energy efficiency first principle".

According to the directive's proposal, a **zero-emission building** is defined as a **building with a very high energy performance, with the very low amount of energy still required fully covered by energy from renewable sources and without on-site carbon emissions from fossil fuels**.

Additionally, in May 2022, the EU launched the "REPowerEU Plan: Joint European action for more affordable, secure and sustainable energy" to phase out Russian fossil fuel imports. REPowerEU is helping the EU to save energy, diversify energy supplies and produce clean energy. Main actions have been implemented to accelerate the clean energy transition.

As part of this aim to boost renewables, a key role has been identified for buildings in two main ways. The new European Solar Rooftops Initiative will make the installation of rooftop solar panels compulsory for all new residential buildings by 2029, with earlier timelines for large public and commercial buildings. The Commission has also set a target to double the current deployment rate of heat pumps, totalling 10 million units over the next 5 years.

Other measures announced include the increase of the binding target of the Energy Efficiency Directive (EED) for 2030 from 9% to 13%. The plan also calls on the European Parliament to enable additional energy efficiency gains in buildings through the ongoing revision of the Energy Performance of Buildings Directive (EPBD). Alongside this, REPowerEU encourages member states to implement supporting measures including reducing VAT rates for building insulation and high efficiency energy systems.

In this sense, the new Directive 2023/1791 on energy efficiency was published in September 2023. In its article 6, the Directive states that without prejudice to Article 7 of Directive 2010/31/EU, each Member State shall ensure that at least 3 % of the total floor area of heated and/or cooled buildings that are owned by public bodies is renovated each year to be transformed into at least nearly zero-energy buildings or zero-emission buildings in accordance with Article 9 of Directive 2010/31/EU.

Finally, the EPBD was updated in 2024 according to the Commission's proposal (Directive 2024/1275/EU), to increase the rate of renovation in the EU, particularly for the worst-performing buildings in each country, in line with the proposals included in the mentioned Communications.

In addition to the measures already mentioned, others included in the revised Energy Performance of Buildings Directive are:

Legal Framework in Europe.

- a binding target to decrease the average energy performance of the national residential building stock by 16% by 2030 in comparison to 2020, and by 20-22% by 2035, based on national trajectories.
- increased deployment of solar technologies on all new buildings and certain existing non-residential buildings where technically and economically feasible, and ensuring that new buildings are solar-ready (fit to host solar installations).
- a gradual phase-out of boilers powered by fossil fuels, starting with the end of subsidies to stand-alone boilers powered by fossil fuels from 1 January 202.
- one-stop-shops for the energy renovations of buildings for home-owners, small and medium-sized enterprises and other stakeholders.
- further roll-out of recharging points for electric vehicles in buildings, removing barriers to their installation, enabling smart charging and introducing measures for bike parking in buildings.
- data collection and sharing, to improve knowledge on the building stock and awareness on energy consumption in buildings

Other elements to highlight as part of the revision of the EPBD is the introduction of Whole Life-Cycle Carbo (WLC) reporting for all new buildings from 2030 and all large buildings from 2027. In this sense, the European Commission elaborated a WLC roadmap for the built environment, expecting to contain operational and embodied carbon milestones between the present day and a completely decarbonised built environment sector by 2050. Those elements have also been incorporated in this Policy Roadmap as part of the LCA assessment carried out during the analysis of EXCESS technologies. While PEBs and PEDs (Positive Energy Districts) are not part of these directives, PEBs and PEDs elements have been transposed such as high Energy Efficiency standards, district and community-based approaches for energy efficiency and renewable or solar readiness of buildings when renovating them.

Legal Framework in Europe.

It is also worth mentioning, for its contribution to PEBs, the Renewable Energy Directive (2009/28/EC), revised in 2018 and legally binding since June 2021. The existing directive sets the overarching European target for renewable energy and includes rules to ensure the uptake of renewables in the transport sector and in heating and cooling, as well as common principles and rules for renewables support schemes, the rights to produce and consume renewable energy and to establish renewable energy communities, and sustainability criteria for biomass.

The directive also establishes rules to remove barriers, stimulate investments and drive cost reductions in renewable energy technologies, and empowers citizens, consumers and businesses to participate in the clean energy transformation. Furthermore, the revision of the directive strengthens energy sharing and energy communities that may be important policy frameworks for PEBs and PEDs.

In July 2021, the Commission proposed another revision to accelerate the take-up of renewables in the EU and to help reach the 2030 energy and climate objectives. The directive sets a common target – currently 32% – for renewable energy in the EU's energy consumption by 2030. The proposed revision and the REPowerEU plan, presented in May 2022, suggests further evolution of the target to accelerate the take-up of renewables in the EU, including by speeding up the permitting processes for the deployment of renewables.

The realisation and detailed planning of these EU-level targets, strategies and directives are mostly left for the individual Member States, so the practices and emphases may vary in the individual countries. Also, regional and local legislation, building codes and energy laws influence what can be done.

Legal Framework in Europe.

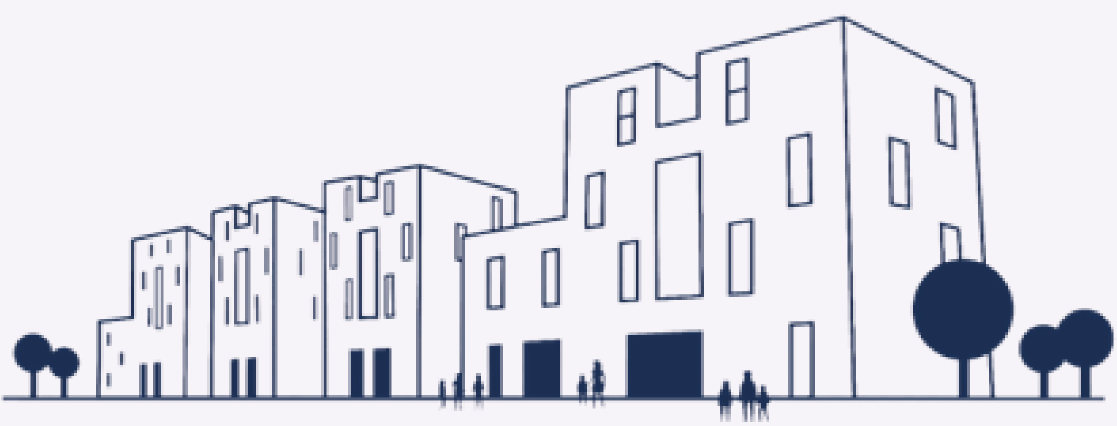
How local and regional planning instruments (e.g. Sustainable Energy (and Climate) Action Plans (SEAPs/SECAPs), environmental strategies, urban plans, Smart Specialisation Strategies, CityKeys - Smart City indicator set) can promote the development of Positive Energy Buildings (PEBs) across Europe and have been analysed in the EXCESS project.

All these elements have been considered and integrated in the elaboration of this Policy Roadmap aimed at providing national/regional and local governments with guidelines for the transition from the current construction model to a sustainable one, in economic, social and environmental terms.

The purpose of this Policy Roadmap is to facilitate local and regional administrations to adopt measures to optimise the energy efficiency of their building stock by introducing in their energy and urban strategies and planning the concept of building, neighbourhood or district of positive consumption, built on European policies, strategies and processes that are favourable and supportive to PEB concepts.

This has been possible thanks to the intense work developed in the EXCESS project that has allowed, through multiple analyses and the development of four pilot actions, to establish the technical, financial and legal bases to facilitate the deployment of building, neighbourhood or district of positive consumption.

Social housing complex
in Hasselt, Belgium (Coastal climate)



4.What is a PEB and why include it in local and regional energy planning?

In this section we will describe the PEB concept as defined in the framework of the EXCESS project, and we will justify the need to integrate this concept in urban and energy planning at local and regional level as a key aspect to achieve the objectives of decarbonisation of the building sector.

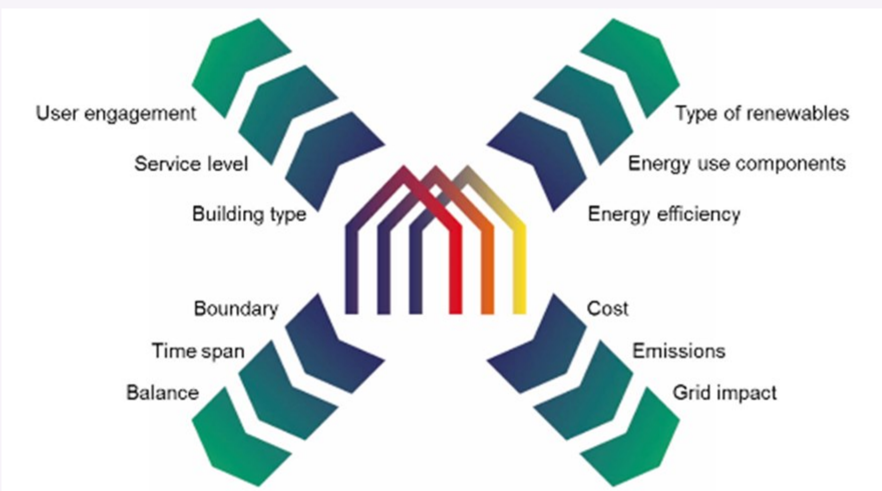


FIGURE 2: Elements to be included in the PEB definition, defined in EXCESS

EXCESS defines a positive energy building (**PEB**) as an "**energy efficient building that produces more energy than it uses via renewable sources, with a high self-consumption rate and high energy flexibility, over a time span of one year**".

What is a PEB and why include it in local and regional energy planning.

A high-quality indoor environment is an essential element in the PEB, maintaining the comfort and well-being of the building occupants. The PEB is also able to integrate the future technologies like electric vehicles with the motivation to maximise the onsite consumption and share the surplus renewable energy.

- EXCESS considers mainly residential buildings, while looking at the role of the building in a bigger context, especially through impact to the energy networks. In the assessment of the building, the energy needs for other than residential activities, e.g. commercial or public services are excluded, while the energy use for the shared spaces is included.
- The local generation includes the energy produced at the building site, with technologies placed in/on the building or building site and technologies incorporated within the building elements.
- The energy need components considered in EXCESS are heating, cooling and electricity. Heating both includes space and water heating. Electricity includes the lighting, plug loads, ventilation and the electricity needs for the shared spaces such as lighting in common zones and elevators.
- EXCESS uses the definition of renewable energy from the European RES directive, which defines it as energy from renewable non-fossil sources, e.g., wind, solar, hydro, geothermal or biomass.
- High self-consumption rate in PEBs contributes to minimising both the emissions and the negative impacts to the grid. The self-consumption rate can be increased e.g., by demand response and energy storage solutions.
- Also, PEBs help to flexibilize the energy system, highly important with a higher share of renewables and can promote sector coupling.
- Indoor environment consists of thermal, visual, and acoustic environment and indoor air quality.
- The life-cycle effects on costs and emissions should be considered in the planning and analysis of PEB.

What is a PEB and why include it in local and regional energy planning.

As mentioned in Chapter 1, the European Commission has recognised the crucial role the building sector plays for achieving the EU's energy and environmental goals. Member States and local authorities also have an important role in implementing policies oriented to PEBs. It has also been noticed that at the same time, better and more energy efficient buildings improve the quality of citizens' life while bringing additional benefits to the economy and society. So, to boost the energy performance of buildings, the EU has established an extensive legislative framework that includes the Energy Performance of Buildings Directive and the Energy Efficiency Directive.

As mentioned in the previous chapter, both directives were amended as part of the Clean Energy for all Europeans package, in 2018/2024 and 2023. In particular, the Directive amending the Energy Performance of Buildings Directive, EPDB 2018/844/EU, introduces new elements and sends a strong political signal on the EU's commitment to modernise the building sector considering technological improvements and increase building renovations. The EPBD was updated again in 2024.

All these goals are very relevant and in line with the EXCESS PEB definition and general objectives in the EXCESS project. The definition of the EXCESS project also corresponds well with the suggested pathway forward set out in the EU energy regulatory framework and with the EU long-term vision for a prosperous, modern, competitive and climate neutral economy by 2050.

The EXCESS definition and concept are especially well in line with the ideas on citizen empowerment and user comfort underlined in several of the regulations and vision documents. The documents also refer to the interaction with the grid and the (future) integration of EVs. Energy efficiency is particularly highlighted in the EU's documents, as well as the need to cover the remaining need by renewable energy.

For all the above, the strategies defined in this document are focused on supporting policymakers to promote PEBs and are in line with the objectives proposed by the European Commission in the long term, including a list of measures and indicators that could be integrated into local and regional authorities' policy and planning frameworks.

Apartment building in Helsinki, Finland (Nordic Climate)

5.Main Barriers.

The main barriers identified in the PEBs are summarized in this chapter. These were collected during the development of activities previously reported, consisting in the identification of demo location regulatory and market incentives and barriers for implementing EXCESS PEBs, and the results of multiple interviews with stakeholders.

This analysis is key to sizing the measures that have been included in this Policy Roadmap.

The main barriers are:

Technical

- Complexity of the PEB concept.
- Lack of integrators and interdisciplinary teams.
- Lack of actors providing services that cover the whole chain from planning to operation and maintenance.
- Constant emergence of new technologies and new ways of using them.
- Lack of tools for the coordinated control and optimisation of the energy system.
- Pronounced need to consider the local conditions in the planning of PEBs.

Regulatory and legal barriers

- Immaturity of regulations.
- Fragmentation of energy regulation (different fields and governance levels).
- Inability of the regulations to handle different ownership structures and energy choices.
- Tight restrictions in historic buildings in combination with renewable installations.

Social

- Lack of public awareness.
- Multi-owner decision making (in some countries).
- Affordability of PEBs.

Main Barriers.

Financial

- Lack of existing examples of cost-benefit analyses of PEBs (life cycle).
- Typically, high investment costs of PEBs.
- Wide range of design options > significant variation of the costs.

Urban Planning

- Lack of including PEBs into urban planning leading to issues and higher costs during implementation.
- Competition of PEB with existing infrastructure needs to be considered.

Lack of skilled labourforce

- The construction sector suffers from high labour costs, often used unskilled labor.
- Technical know-how on new solutions often not available.

Technical barriers

First, the complexity of the PEB concept requires different approaches depending on the location, whether the building is in the city or in the countryside and depends on the local conditions, related e.g., to climate or availability of solar irradiation (which can be affected by shading from surrounding buildings, terrain, or vegetation). This is a condition that should be considered in the definition of the Policy Roadmap.

Second, the necessary technologies are already available but can be further optimised. As the building stock is highly heterogeneous technologies need to adaptive to specific local conditions, having modular character. In addition, the technical complexity also means that there are few providers that can offer a complete solution or a total solution in the market, which means that there are few experts available, which also means that competition is very low.

Since the technological concepts often require different professional groups, it is important to establish interdisciplinary projects or a really good interaction between those involved. It is also important to point out that there is a lack of qualified workers and that the sector's own professionals must be constantly trained to be always up to date with the latest technology.

Main Barriers.

The specific benefits of a system must come through **systematic analyses** over longer periods of time to help the concepts achieve a breakthrough. Emphasis should also be placed on **coordinated control and optimisation** of the energy system.

In addition to good planning, business models should be linked to maintenance, and performance-based contracts should be used. Thus, in the long run, the efficiency of the maintenance of a building becomes an important element in this process.

Additional technological barriers are referred to managing the interplay of energy production and demand, as well as grid interaction, architectural implementation of renewable technologies, and transferability.

Regulatory and legal barriers

The **fragmentation of energy regulation** (gas, heat, electricity) is one of the main regulatory barriers. Linked to it and related to the PEB concept, the lack of specific regulation is also a big challenge. Thus, in many countries in Europe it is still not possible or there are problems related to benefiting or profiting from surplus energy through selling it to other buildings, or grid connection. In other countries, the regulation does not allow to make an energy balance between the production and the consumption.

In countries like France, ground source drilling currently is not allowed. In addition, PV and PVT have to show life cycle emissions, making them uncompetitive to renewables from the grid, that don't need to show life cycle emission.

There are also specific challenges for introducing the PEB concept caused by regulation and in high protection of historic buildings and heritage sites. Fire regulations are also a big barrier. In addition, the current building routine and permission processes are not suited for new technologies.

The lack of regulation related to the ownership structure and energy choices should be highlighted. There is not yet a legal basis in place, for example, to be able to include photovoltaics on an apartment building appropriately when there are several owners in the house.

The involvement of various levels in many countries and many departments in administration may cause challenges to the development of appropriate regulatory framework for PEBs and thus lead to barriers.

Additional regulatory barriers are referred to regulation on delivering and managing heat grid, urban integration of the area, (building) authority, current use restrictions by building authorities and legal barriers related to neighbourhood identity.

Main Barriers.

Social barriers

Social barriers included issues with perceptions related to comfort, user-friendliness, maintenance etc. and lack of information, attitude towards and affordability of PEBs.

There are issues related to the lack of information. The concept of PEB is not familiar and there is not enough knowledge on what PEBs can offer. It is unclear what constitutes a PEB and how the field is developing, even among experts. Issues related to comfort, user-friendliness, maintenance, and behaviour changes needed from residents of PEBs are not very well communicated or explained. Tenants of the building may lack knowledge about the system and how it works. There is a need for information and instructions may vary between various groups of people. This may become a burden for e.g. housing organisations.

The demand for PEBs can remain low e.g. also because potential residents do not see anything special in living in a PEB compared to a conventional house.

Affordability of PEBs, especially for several citizen groups, comes up as a societal barrier. Other issues are that private renting market is getting more and more expensive and that PEBs are not affordable to average income people.

PEB is a complex concept creating additional needs to get the builders on board and motivated. Thus, additional societal barriers refer to the engagement of residents, knowledge of users/ residents and their profile e.g. for the development of information programs.

Financial barriers

Innovation is one of the main drivers for improving the energy efficiency of buildings. But this innovation often results in a financial challenge for the construction companies or the owners with additional costs for new solutions.

At the current stage of development of technological concepts, there is a wide range of design options — both regarding the buildings, the technologies and the materials used, multifunctionality or type of exterior design, etc., so that the costs vary significantly. In addition, current implementations of PEBs are mostly embedded in demonstration projects and there is no standardisation. The costs for achieving PEBs is also different across climate zones, while in Southern Europe large surfaces for PV and small buildings may achieve PEB standards, in northern Europe more complex and costly set ups are needed to satisfy electricity and heat demand.

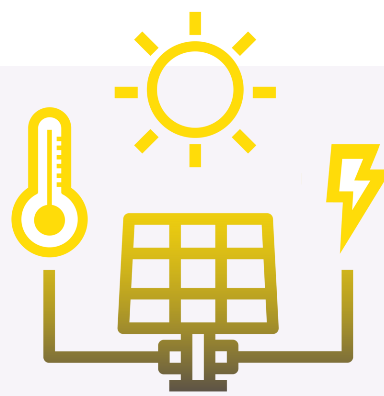
Main Barriers.

It is therefore clear that innovative solutions must be linked to business models that ensure acceptance on the broad market.

The framework conditions will be set at the national level, and regional governments can support with important financial resources to drive the massive deployment of PEBs. **Therefore, financing and incentive schemes at the national and regional level play a major role in promoting energy efficient buildings (PEBs).**

At present, the concepts are still characterised by an increased effort in planning and higher initial costs. In addition, many advantages, or specific benefits of the PEB concept, can only be shown or demonstrated over a long period of time (ideally over the whole product life cycle).

A holistic calculation would then consider not only the planning, manufacturing and construction costs, but also the lifetime costs. In most cases, however, such an analysis is not carried out in the run-up to an investment due to resource-technical considerations or also due to a low degree of specification/lack of information. Also, PEDs often need integrated solutions to be cost effective (eg combing PVT with ground source heat pumps), for which the current subsidies for individual technologies are not suitable. Funding for serial or modular renovation is not available in most Member States, but only for individual technologies.



Greater focus on de-risking solutions is also needed. This includes public guarantees for private loans and mechanisms to support pioneering private companies that are developing new technologies and solutions crucial for achieving EPBD's ambitions, despite the high risk of failure.

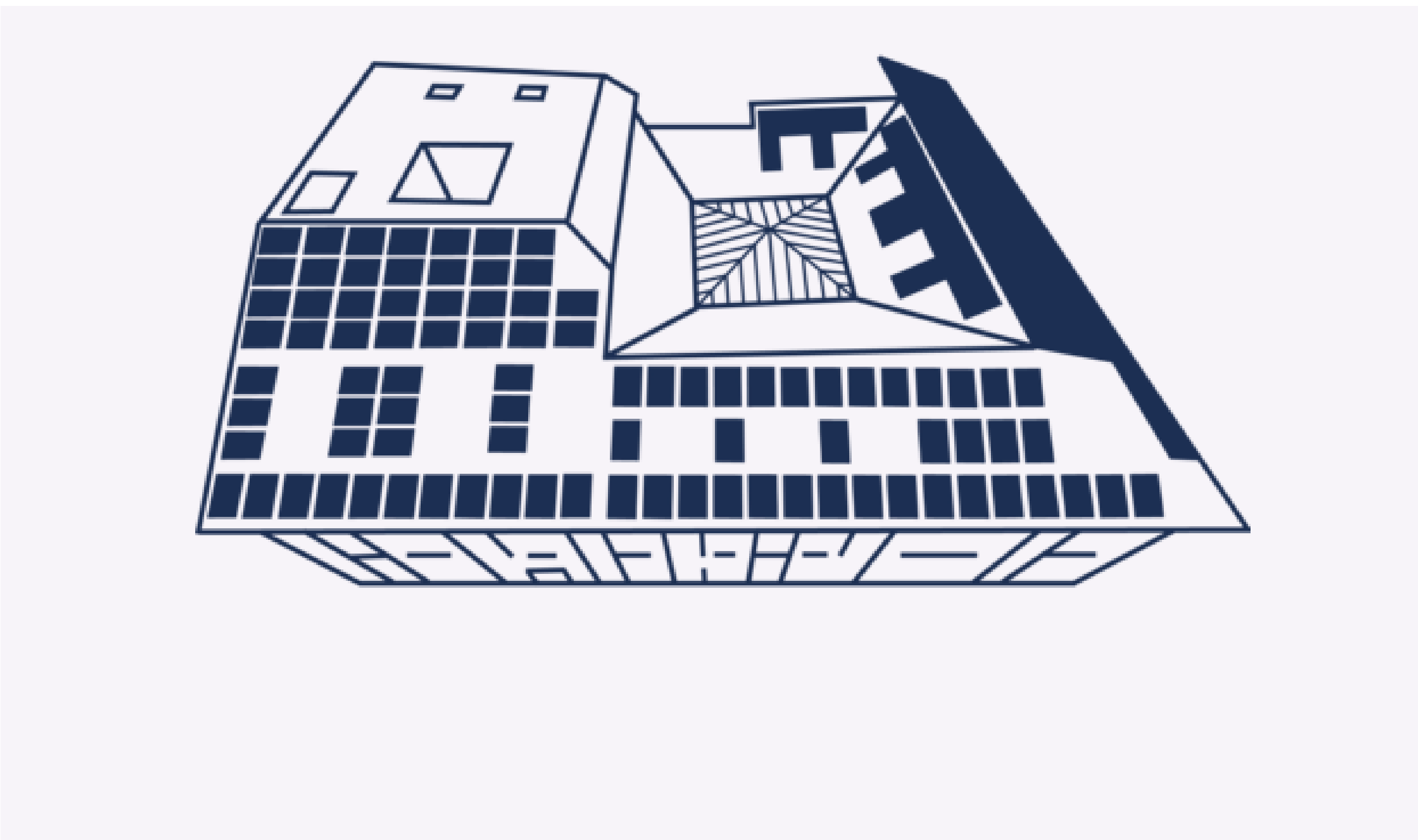
What about organisational/stakeholder related barriers? Who drives PEBs? Construction companies are not very interested. Energy suppliers only go for simple technologies. Housing associations want low OPEX, reducing the energy expenses incurred to maintain the day-to-day of the buildings. In this sense, a set of generic, replicable business models have been defined in the EXCESS project, each addressing specific technical elements as well as actors in the value chain. The results of the business model developed has been an important input for an adequate seizing of the policy measures included in this Policy Roadmap.

Main Barriers.

Urban Planning

So far PEBs are not included in urban and spatial planning. Not all placed are suitable for PED for example if a district heating system is available it may be more cost-efficient to decarbonize district heating than to place PEDs. Energy suppliers may be reluctant to install competing technologies. The lack of integrating of PEDs in urban planning may lead to additional infrastructure needs. Districts that want to install PEDs may not have sufficient spaces, leading to possible higher technology costs. Also, opportunities such as waste heat or ground source heating/cooling source are not sufficiently assessed.

Historical residential building in Valladolid, Spain (Mediterranean climate)



6.Findings from PEB demos and stocktaking.

6.1 Findings from stocktaking

The stocktaking exercise carried out in the EXCESS project identified 58 PEBs with combined surface area of 400,314 m². 26 PEBs were located in the oceanic climate zone (229,874 m²), 13 PEBs in the continental climate zone (85,121 m²), 8 PEBs in the Mediterranean climate zone (20,259 m²) and 5 in the Nordic climate zone (24,279 m²). In oceanic climates the majority of PEBs are commercially used (53.8%), followed by residential and public use (42.3% and 23.1% respectively). In Mediterranean and Nordic climates commercial uses were most frequently encountered, whilst in continental climates residential PEBs are mostly represented in the sample.

In addition to the stocktaking exercise, 10 case studies were developed in the context of the EXCESS project. The detailed case studies go beyond the data collected by desk-research during the stocktaking exercise, to provide more in-depth information regarding the local initiation context, integrated technologies, building performance indicators, levels of stakeholder engagement, challenges and opportunities as well as replication potential.

The final conclusions of the stocktaking exercise and case studies are presented below, suggesting further research and recommendations on the actions to take and main points to consider in order to promote PEBs.

Most PEBs were located in France, with 46.6% of PEBs located in this country. Germany takes second place with 17.2%, followed by Norway (6.9%). European territories where comparatively few or no PEBs could be identified include Southern Europe, Eastern Europe and the Baltic States.

Many factors may influence the clustering of PEBs in France and Germany. However, attractive and comprehensive funding schemes exist in both countries.

Findings from PEB demos and stocktaking.

Finding 1. MS should analyse, adapt and adopt successful French & German grant / loan / subsidy schemes.

Finding 2. Also, EU funding for innovative PEB/PED pilots should focus on Southern Europe, Eastern Europe and the Baltic States.

PEBs are rarely found in areas where a district heating system exists.

Finding 3. Decarbonising established grids likely represent a better investment in terms of cost / benefit than installing new heating technologies in each building serviced.

Examining the key technologies installed in the buildings, photovoltaic (PV) panels are by far the most common, with all PEBs using these to some degree. Energy storage systems are integrated into PEBs relatively evenly across climate zones. Another very frequently installed technology is an energy efficient mechanical ventilation system (81%), which is often coupled with heat recovery systems (86%). In 70% of cases the integration of an energy management system and sensors was mentioned, but this figure is likely to be much higher. Energy efficient heating is another common feature incorporated in PEBs (69%), with energy efficient cooling being mentioned much less often (33%).

In addition to photovoltaics and solar thermal collectors, geothermal energy is often used as an efficient and renewable source for heating and cooling for positive energy buildings. For energy storage, both thermal tanks as well as batteries are being used in the featured case studies. Reducing energy consumption is also a clear priority in PEB design, with energy efficient lighting, appliances and also occupant behaviour being recognised as important to reduce overall energy demand.

With regard to thermal management of buildings, a passive house approach is commonly used, with the specification of high insulation levels, a prioritisation for achieving high levels of air tightness and installing mechanical or hybrid ventilation systems, in conjunction with heat exchangers to capture energy from exhaust air. In some cases, energy is also recovered from elevators and servers. A further strategy adopted in many buildings is to use a building's solid structural core for thermal storage with heat being stored and slowly released over time.

Findings from PEB demos and stocktaking.

Going beyond building-related energy concerns, it should also be noted that many of the PEBs in the case studies incorporate additional sustainability features, such as rainwater collection (for irrigation and non-potable purposes), providing showers and lockers for cyclists to encourage non-motorised or low-emission transport, incorporating EV-charging facilities, etc. The inclusion of such features indicates that PEB design is guided not only by the desire to achieve net energy positivity but is also driven by an integrated and holistic view of sustainable architecture and urbanism.

Finding 4. Building regulations / standards should facilitate the installation of PV and thermal energy storage

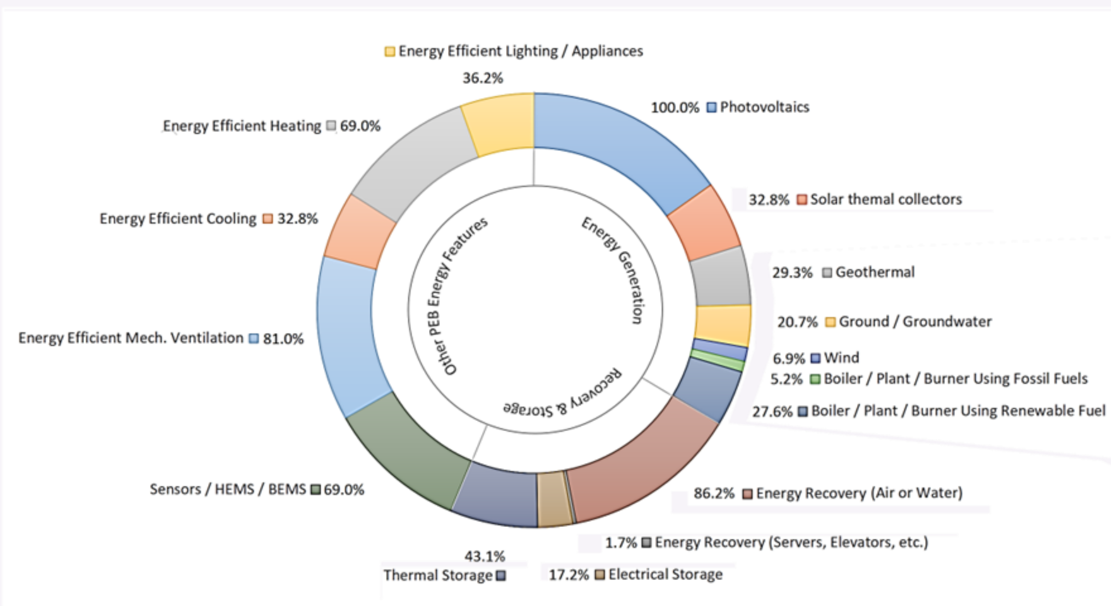


FIGURE 3

PEB building typologies: 40.3% of buildings in our dataset are commercially used, 38.8% and 20.9% are public buildings. Limited public funding and technical support should be focused on non-commercial buildings. Minimum performance standards should mandate PEB offices.

Findings from PEB demos and stocktaking.

Finding 5. Limited public funding and technical support should be focused on non-commercial buildings. Minimum performance standards should mandate PEB offices

PEBs that are single family residential dwellings (19.4%) are more common than multi-unit residential developments (13.4%).

Finding 6. The retrofit of multi-unit residential buildings must be enabled more actively, through information, mediation among owners, economic incentives, etc.

Educational buildings are among the most common PEBs found in Europe. No health or emergency services buildings were found that are energy positive and only one industrial building fulfilled the PEB criteria.

Finding 7. All levels of government should prioritise the renovation of educational buildings and other public buildings via forward-looking procurement practices.

Complex projects require the collaboration of a greater number of specialist firms than is typically the case with conventional real estate development projects. Interaction of actors in the conception, design, planning and construction of buildings is a key feature for successful construction projects. In the case of positive energy buildings, collaboration between specialist firms and the deep engagement of the client and building users appears to be even more crucial. An average of 7.7 partners were involved per PEB in the 58 cases analysed. In the context of one PEB, 24 companies were named. Presently, 52% of PEBs are rated as having very high or high stakeholder engagement and 33% are rated as having medium-high engagement. Medium levels of stakeholder involvement were attributed to 14% of the cases, but this figure should be considered with caution as information pertaining to the buildings was not sufficiently detailed to draw definitive conclusions.

Finding 8. Solving complex problems requires high levels of stakeholder collaboration.

Finding 9. Business models underpinning PEB development. The most effective business models seem to be created by bringing together construction companies that have the right skills and are experienced in collaborating with one another.

Findings from PEB demos and stocktaking.

Finding 10. All stakeholders (especially SMEs and smaller) in the construction / renovation value chain should have access to training and certification schemes.

The average cost for PEB renovations stands at approx. EUR 1700 / m². For new construction the average price lies at around EUR 2,160 / m².

Finding 11. Focus on driving down costs for energy renovations as well as linked PEB technologies should be a priority.

Understanding that grid-integration is a key factor for realising PEBs, nearly-zero energy buildings and for decarbonising our built environment generally, data gathering and pinpointing innovative approaches to grid connectivity and energy trading remains a priority. Bi-directional grid interaction (at a city, neighbourhood or building-group scale) plays an important role in enabling buildings to achieve net-positive energy balances.

Finding 12. A key challenge - that when overcome would catalyse the upscaling of positive energy buildings significantly - is the integration of PEBs into local thermal and electrical grids.

To showcase the results of the stocktaking exercise, the PEBs were mapped using Geographic Information System (GIS) software and the map has been uploaded to the EXCESS website, to provide visitors with an overview of PEBs in Europe and enable them to find basic information for each project. Presently, the map includes data on building location, their status and (planned) year of completion, the EXCESS climate zone as well as surface area.

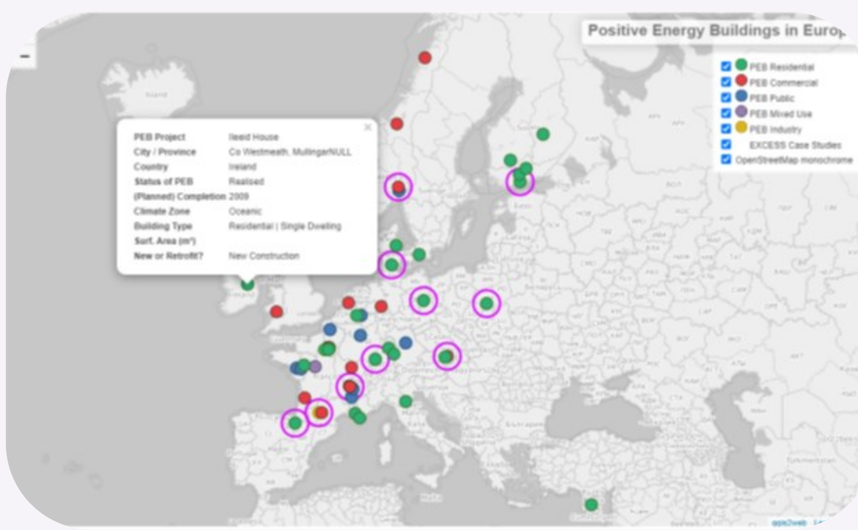


FIGURE 4


≤ 5 A
6 à 10 B
11 à 20 C
21 à 35 D
36 à 55 E
56 à 80 F
81 à 110 G
111 à 145 H
> 145 I
Forte émission de GES
≤ 50 A
51 à 90 B
91 à 150 C
151 à 230 D
231 à 330 E
331 à 450 F
451 à 590 G
591 à 750 H
> 750 I
Bâtiment énergivore

7.Lines and axes of intervention.

The promotion of PEBs from a building, district, , city and regional level should be conceived as one of the pillars on which a new, more sustainable construction model is based, aligned with the objectives of the European directives on energy efficiency, renewable energy and waste treatment.

For this, the present Policy Roadmap aims to promote PEBs actions in buildings, housing, infrastructure and public space that tend to improve the efficiency of the resources that are incorporated and used for it, promote the greater efficiency of urban environments and promote the social cohesion of cities and accessibility.

In any case, it is essential that the demand stimulus actions proposed in this Policy Roadmap are directed towards the development of competitive and specialisation capacities of the construction sector around the new opportunities associated with PEBs.

All these efforts will allow the generation of quality, safe and stable employment, adapted to the new requirements and objectives pursued by this new model, which must necessarily alleviate the structural difficulties of the sector in some European countries and regions (high temporality rate and low qualification).

The reformulation of the business models of the companies in this sector, developing all the potential offered by the PEBs towards new processes and new products, the strengthening of their image oriented towards sustainability, and a greater integration of all the actors in the value chain, will be key elements in this process.

Therefore, the measures included in this Policy Roadmap aim to establish the basis for a greater specialisation of companies in the construction sector around PEBs, as a nuclear element of their business strategies, improving their productivity and competitive position in national and international environments.

Lines and axes of intervention.

In this sense, the lines of action for the specialisation and formation of human capital around PEBs should be directed, among others, to aspects such as the development of specific itineraries on the high volume of employed and unskilled unemployed linked to the sector, the improvement of training offers for self-employed and micro-SMEs, as well as the identification of professional profiles on which this new model of sustainable construction and rehabilitation is based.

It is intended to forge a PB sector with quality, regulated and regularised jobs, with adequate qualifications and professional accreditation procedures for workers that provide a stable, competitive and prosperous sector, oriented towards the new market niches generated around PEBs, while promoting the incorporation of the social economy.

Another of the key elements to promote PEBs is the awareness of society (productive sector and citizenship) of the need to develop actions aimed at improving the use of resources and energy efficiency in their facilities and buildings. Citizens and neighbouring communities are the main actors in the change of action towards the rehabilitation, conservation and energy improvement of buildings and cities, and their better understanding of the impact of PEBs will be a key element for their generalisation.

As far as business is concerned, the immediate benefits associated with PEBs are the reduction in energy use and intensity, which translates into positive effects on efficiency by freeing up resources that can be allocated to other economic activities, reducing investments related to energy supply, reducing production costs and consequently improving competitiveness. To do this, it is necessary to implement specific actions for each of the productive sectors, aimed at achieving a change of culture aimed at achieving increasingly efficient buildings, in line with the PEBS, and to promote an offer of specific funds to finance these investments with a longer period of return, in order to meet the objectives set in terms of energy consumption and emissions in the EU.

For all this, the present Policy Roadmap aims to facilitate that citizens and companies implement activities aimed at achieving PEBs, through measures to stimulate potential demand, the awareness of society towards sustainability and the orientation of the regulatory framework.

Lines and axes of intervention.

In addition, PEBs actions should be able to respond to the needs arising from the population sector with fewer resources and at risk of social exclusion. Promoting social inclusion and the fight against inequalities and poverty that affect these communities necessarily involves betting on the physical, social, economic and environmental regeneration of their residence environment.

Therefore, the present Policy Roadmap also aims to strengthen the concept of PEBs as guarantor of the social function of housing, combining the interests of owners, companies, building managers and technicians, financial institutions and public administrations, and facilitating access to decent housing for vulnerable groups.

In this process, the rehabilitation and enhancement of public buildings and public space requires special attention, as it is an opportunity not only for the promotion of demand as spaces for integration and accessibility to services for users, but also as “demonstration spaces” for the integration of PEBs technologies that improve their management and maintenance.

In addition, it should be considered that appropriate technical solutions for the PEB are highly dependent on the location and climate. The climate for instance can be either a barrier (in Finland, high seasonal variance of energy needs and supply) or an opportunity (in Spain, good availability of solar energy). The cost optimal analysis and the subsequent business models for PEBs developed in the framework of the EXCESS project will serve as an efficient tool for policy makers as is stated in this Policy Roadmap.

Finally, it points out that there is currently a broad regulatory framework, emanating from regional, national and European bodies, responsible for setting certain objectives and obligations in the field of energy efficiency in buildings.

However, it is necessary to implement an appropriate complementary system of actions, which would allow to significantly increase the activity in PEBs, as the demand to adapt buildings to this concept that can lead to significant savings, in addition to adequate feedback for the implementation of subsequent programmes.

For this reason, the present Policy Roadmap aims to establish the basis for a regulatory framework for PEBs, which facilitates their development, a better interrelationship between all its actors, and a more sustainable social development, facilitating universal access to PEBs solutions.

In short, it is necessary to complete the regulatory development related to PEBs, which overcomes the shortcomings of the current legislation, ensures its compliance and removes the barriers that prevent its implementation.

Lines and axes of intervention.

The successful realisation of PEB projects requires the participation of many different stakeholders from early phases of the project in order to manage complexity, respond to needs and address requirements from different perspectives. The inclusion of a wide variety of stakeholders is also a crucial element for developing strategies or regulations that support the implementation of PEBs. Also, end users need to be encouraged or rewarded for a correct energy use. It is important to raise the awareness of all stakeholders and to educate them on all energy efficiency and local RES integration.

The strategic lines and axes of intervention are described below. They are focused on providing national/regional and local authorities with guidelines for the transition from the current construction model to a sustainable one, in economic, social and environmental terms. It has considered the principles mentioned above, as well as the conclusions of the interviews conducted among experts in the building sector across Europe.

This Policy Roadmap details concrete steps to foster PEBs development to increase renewable energy generation, improve energy efficiency and decarbonise building stock in local and regional authorities' policy and planning documents in Europe.

L1. Standardisation of the PEB concept across Europe. EU LEVEL

The harmonisation and standardisation of the PEB concept would mean that the EU, as well as all actors in the building sector, and public authorities and financial institutions, would be able to compare building data from Member States far more efficiently and directly and assess national progress on setting and reaching PEB building targets and make fair comparisons. PEB definitions should also consider the different climate zones, as it is more challenging to reach PEB level in the north. A first definition of PEB has been developed in the framework of the EXCESS project. **See chapter 4**.

This recommendation around harmonisation and standardisation should be integrated into key EU Directives and work streams such as the EPBD. The harmonisation of the PEB concept and target setting across the EU would ensure that data around the PEB impact is fully comparable between Member States and nations will be able to learn best practices from each other more efficiently. This will also, crucially, make PEB transition more manageable for the construction sector which will be implementing PEB projects in practice on sites across the EU.

Líneas y ejes de intervención.

L2. Understanding institutional arrangements and powers that influence PEB developments

During the EXCESS project it has been highlighted that the leverage points for the effective roll-out of PEBs differ, depending on the governance structure of a particular country. Whilst in some contexts urban planning authorities provide concrete frameworks for spatial interventions, the regional authorities in other countries appear to have greater power to affect sustainability transitions in the built environment. Considering this, diversity of institutional arrangements there is no “one size fits all approach”, but the activities need to be localised:

L2.1 Clarify the roles of different governance levels and build bridges for co-operation.

L2.2 Work in the existing structures to advocate for change at national or even European level (join a city network that advocates on your behalf, take part in EU consultation processes, etc.).

L2.3 Understand who are the decision makers for revisions to building standards / codes, what kind of vested interests they may have to retain the status quo and how local and regional political stakeholders might be able to lobby for amendments.

L3. Improving society’s knowledge of PEBs and implementable technologies

Creating awareness/reputation and demand for PEBs, as well as providing information and support it in various ways is a key element. Often the investment costs are considered when making the decisions. So, it would be important to explain the advantages and benefits of PEBs (e.g. long-term economic return on investment) and to quantify the value-added of PEBs to end-user.

In this sense, a cost optimal analysis has been carried out in the EXCESS project, identifying the cost optimal combinations of current and innovative technologies covering the four climate zones (Nordic, Continental, Oceanic and Mediterranean) of the project scope for multi-store residential buildings to ensure high replicability across Europe. The analysis showed that not all PEB technologies reduce global costs. There is a range of factors that impact the economics of the chosen technologies, such as the shape of the building, the climate zone, or the overall technological systems in which they operate. reating awareness/reputation and demand for PEBs, as well as providing information and support it in various ways is a key element.

Lines and axes of intervention.

Also, the energy prices play a critical role for making PEBs economical. More clarity should be gained on the values of flexibility provision of PEBs as the related revenues could further reduce costs. The analyses revealed that there are situations possible where the PEB standard can be reached just with PV and without any other renovation measures in particular in Southern Europe. In any case, the report also showed that a system view on costs is necessary. In this regard, individual technologies may not be cost efficient, but they can be enabling technologies that make the entire technology system cost efficient. The conclusion of the cost optimal analysis is presented in Annex 2.

Although this is a preliminary analysis and the results are very valuable for spreading the PEB concept at European Level, further studios should be carried out to incorporate more technologies, climate zones and other types of buildings.

In consequence, the measures proposed are:

At National/European level:

L3.1 Needs for longer-term studies to show the energy savings compared to conventional systems and the technologies used. PEBs must be examined by calculating the costs for PEB developments compared to traditional construction or renovation. As a reference, see the conclusions of the cost optimal analysis of the EXCESS project in Annex 2.

L3.2 Building a central website and a strong brand for PEBs.

L3.3 Definition and KPIs are needed in order to promote the PEBs. Develop common, easily understandable Key Performance Indicators for PEBs, to avoid the most common misunderstandings of the concept.

At Local/Regional level:

Providing easily and clearly accessible information, data and processes for project developers and planners is recognised as an important success factor. Building is a big investment and, therefore, it is important to have independent information. Local and regional governments are generally perceived as a good, trustworthy source of information.

Lines and axes of intervention.

It was also pointed out that the successful realisation of PEB projects requires the participation of many different stakeholders from early phases of the project in order to manage complexity, respond to needs and address requirements from different perspectives. Also, end-users need to be encouraged or rewarded for a correct energy use. It is important to raise the awareness of all stakeholders and to educate them on all energy efficiency and local RES integration.

Municipalities and regional authorities can support building designers from the beginning through other means than mandating or encouraging PEBs in urban plans, such as the following actions proposed:

L3.4 Creation of knowledge centre by regional/local government to make citizens more receptive to PEB solutions.

L3.5 Provide practical guidance through the publication at local and regional levels of best cases and practices (e.g. handbook or information in a visual and simple way), articles and daily news.

L3.6 Promotion of participation at fairs, housing exhibitions, discussions.

L3.7 Facilitating the multi-owner decision making related to apartment buildings.

L3.8 Promote the role of ambassadors to incentivise, guide, and empower the replication of PEBs.

L3.9 Launching awareness raising campaigns and disseminate knowledge.

L3.10 Ensure commitment of the people through an open process and broad stakeholder engagement when developing city or region strategies.

L3.11 Engage homeowners, real estate and pension funds to catalyse the deep refurbishment of their buildings towards PEB performance levels - implementing energy efficiency improvements and retrofitting on-site RES generation, whilst balancing targeted performance levels and the bankability of the whole project.

Lines and axes of intervention.

L4. Improving the knowledge of PEBs to local decision-makers and prescribers

L4.1 Elaboration of a taxonomy of buildings to develop a strategy for the implementation of PEBs. As a reference, the following points are according to the criteria of EXCESS project:

- Attention should be paid on retrofitting solutions that while improving energy performances, protects heritage and increase the value of these remarkable buildings. Special consideration should be given to historic building stock.
- The retrofit of multi-unit residential buildings must be enabled more actively, through information, mediation among owners, economic incentives, etc. Particular attention could be placed on: ramped up information campaigns and advisory services (OSS); better access to grants and subsidies; lower voting thresholds in owner associations; addressing the “tenant-landlord” dilemma.

  Office buildings may be most suited to be constructed / renovated to a PEB standard, due to: energy use patterns (e.g. working day when sun is shining, predictability of consumption, etc,); the building form (e.g. large roof spaces); Corporate Social Responsibility; easier access to financing.
- In areas where district heating and cooling infrastructure exists, decarbonising established grids likely represent a better investment in terms of cost / benefit than installing new heating technologies in each building serviced.
- All levels of government should prioritise the renovation of educational buildings and other public buildings via forward-looking procurement practices.

L4.2 Awareness of the market actors to be fostered.

L4.3 Bringing a network together of organisations and stakeholders that are in any way involved in sustainable construction. Stakeholder ecosystem mappings to better understand the actors and their interest and a real effort to drive behavioral change.

L4.4 Promote one-stop-shop services to ensure that with every renovation the contractor would make suggestions for energy improvements together with tailoring financial information. One-stop-shop services, as a multi-stakeholder approach, would help citizens and public officials fill the knowledge and skill gaps.

L4.5 Voluntary cooperation with administrations.

Lines and axes of intervention.

L5. Promotion of new financial instruments

As mentioned previously, the stocktaking exercise carried out in the EXCESS project identified most PEBs in France, with 46.6% of PEBs located in this country. Germany takes second place with 17.2%, followed by Norway (6.9%). European territories, where comparatively few or no PEBs could be identified, include Southern Europe, Eastern Europe and the Baltic States. Many factors may influence the clustering of PEBs in France and Germany. **However, attractive and comprehensive funding schemes exist in both countries.**

A change from NZEB to PEB leads to higher investment costs and global costs according to the analysis of the EXCESS pilot cases mentioned before. To support the realisation of PEBs, either subsidies are needed to cover the additional costs that cannot be covered by energy cost savings or costs of greenhouse gas emissions must increase to make energy cost savings more profitable. Also, more clarity should be gained on the values of flexibility provision of PEBs as the related revenues could further reduce costs. If PEBs and PEDs should provide benefits to the overall energy system, incentives or tariff structures should be provided to keep self-sufficiency levels high across the entire year.

As part of the EXCESS project, an analysis of available funding alternatives for energy renovations and installation of renewable technology for all building types has been carried out. This analysis covers four European countries of varying climatic zones including Finland, Austria, Belgium and Spain and explores existing funding opportunities for building owners. A summary of funding schemes studied in the EXCESS project, and the main conclusions are presented in Annex 3. The following actions are highlighted from this report:

- Facilitate the access to the different financial instruments. The wide variety of financial schemes is creating challenges for the investors and house owners, as it is sometimes hard to find the right channel.
- Financing combination of technologies. Also, applying for funding from different providers may create challenges in the timing, as the decision making may have different lengths in different institutions. This requires a common PEB definition as well as new ways of formulating the requirements for the funding, and potentially co-operation between the funding agencies. Simplified funding scheme should be defined that incentivises entire technology packages needed for PEB realisation. A good example is the approach tested in Germany called “serial renovation”, which is intended to integrate new technical possibilities for the industrial prefabrication of technology packages (prefabricated facades or roof elements) as well as the possibilities of digitalisation into renovation processes.

Lines and axes of intervention.

This requires new ways of formulating the requirements for the funding, and potentially cooperation between the funding agencies. But also funding schemes that specifically target district level renovations may be of high importance. More holistic funding may require the consideration of new target groups, such as service providers, building renovation aggregators or energy communities.

- Additional criteria for obtaining funds, such as social criteria for low-income citizens next to the above-mentioned sustainability criteria may play an increasing role to mainstream the PED concept.
- It is recommended that the financial incentives should be long lasting and predictable. They should also include funding for planning of renovations. Short-term funding schemes may disturb the market, raise the price levels and lead to hasty decisions on the renovations. Long-term schemes would also allow more time for the planning and implementation, leading to better solutions.

Additional actions proposed in this line are:

L5.1 Identify and enable financial support, e.g. through European Regional Development Funds, setting regional energy objectives and minimum standards.

L5.2 Definition of an innovative finance framework, such as subsidies or low interest rates, for the incorporation of innovative PEB-oriented solutions.

L5.3 Definition of tax instruments that favour PEB solutions, such as taxes reform introducing slightly lower taxes for larger heat pumps, conditions for the transfer of plots of land and reduction of the cost of building permits or property tax if certain requirements are met, abolishment of the building tax that is paid to the city council in case of new construction. These advantages should also be extended in time and not only be reflected during the construction phase, but also during operation in the form of tax advantages.

L5.4 Introducing CO2 tax or an environmental tax.

L5.5 Implementation of measures to facilitate access to private finance for businesses and individuals: agreements with financial institutions, energy as a service.

L5.6 Develop performance-based contracts to also include the maintenance of PEB systems, such as energy service companies (ESCOs). Case of social housing in Denmark, which is partly financed by communal loans and social housing companies can only get an income after the investment is paid off.

L5.7 Innovative financial incentives are needed to promote PEBs at local level. Some cities are already offering financial incentives for low carbon built environment transition, such as ’now or never deals’ where businesses can get funding and only have to start reimbursing it when it is clear that they can recuperate profit from this investment within the first two years.

L6. Boosting new business models around PEBs

A set of generic, replicable business models has been defined in the framework of the EXCESS project, each addressing specific technical elements as well as actors in the value chain**, such as** investors (with the related investment schemes), operators of the model, as well as the core customer groups**.** A summary of the business models studied for the 4 EXCESS demos in different climate zones and the main conclusions can be found in Annex 1.

L6.1 Implementation of measures to facilitate the development of a sector around PEBs.

L7. Promote PEBs in regional/locally owned buildings

A strategic decision at regional/local level is to achieve PEBs in all owned buildings where it is an economically justifiable choice. Pilots, especially driven by public actors, are also a good way to promote PEBs. Transforming or developing new buildings owned by local or regional authorities to a PEB standard has a high-impact way to raise awareness, demonstrating leadership and move towards the decarbonisation of the public sector.

L7.1 Public awareness of public authorities.

L7.2 Adoption and promotion of voluntary standards for rehabilitation including PEBs.

L7.3 Boosting innovative public procurement as a tool for the replication of PEBs, such as performance-based procurement or contracting approach. In this sense, public authorities should be focus on the quality of the interventions in regulated tendering, instead of the lowest price. The lowest price criteria is currently a factor hindering the development and replication potential of PEBs in many European countries.

L7.4 Introduction of the PEB concept in the local/city planning.

L7.5 Initiate and co-operate in developing new local PEB pilots.

L8. Specific means of boosting PEBs in vulnerable groups

Currently PEBs are not cheap to realise: lower costs via subsidies and financial support to avoid negative impacts on poor / marginalised communities is needed. The need for "just sustainability transitions", which incorporate social issues, should be highlighted. Information and support related to PEBs concept is considered especially important as a social opportunity.

L8.1 Ensure that the financial support supports pathways towards sustainability that are fair, especially in suburbs and low-income areas.

L8.2 Creation of a network of energy ambassadors in the context of social housing that attends to the communities and generally creating a new energy culture through information and training on energy in buildings.

L8.3 Promotion of local energy communities with the participation of vulnerable groups for the reinforced new ways for cooperation in the neighbourhood.

L8.4 Promotion of demonstration and pilot projects.

L8.5 Subsidise PEBs in groups more affected by energy poverty to reach the entire collective.

L9. Training of new actors and applications around PEBs

One of the most important barriers is also created by technology: PEB is a complex system, and the planning, construction and maintenance requires integrated design by a well-reported integrator, or even an interdisciplinary team to reach a well-functioning system. There is a lack of these integrators but also in general technology providers and installers with the needed know-how, which create an important barrier.

L9.1 date Reinforcement of the "project management" role, with a solid and experienced team, able to handle the complexity of a PEB project. They must be able to explain the dimensions and the different "layers" of such a project and show that it is technically up to date and transfer the benefits in an understandable way.

L9.2 Promotion of training and certification schemes. All stakeholders (especially SMEs and smaller) in the construction/renovation value chain should have access to training and certification schemes.

L9.3 Promotion of smart energy management tools with user friendly applications.

L9.4 Create tools and processes for peer-to-peer advice and information provision (e.g. so called energy ambassador).

L10. Measures to promote innovation around PEBs solutions at European, local and regional level

L10.1 As mentioned before, European territories where comparatively few or no PEBs could be identified, include Southern Europe, Eastern Europe and the Baltic States. Therefore, at EU level, funding for innovative PEB/PED pilots should focus on these territories. Pilots play a key role in tackling local supply and demand-side fragmentation in the sustainable construction / renovation value chain. Countries in which no PEBs have been built, would arguably benefit most from new pilots.

L10.2 Also, prioritisation of research efforts at local and regional level around PEBs.

L10.3 Promoting collaboration between different knowledge actors at local and regional level working in the PEBs sector.

L10.4 Promotion of innovative strategic projects, initial demonstration projects and pilot projects, which accelerate the deployment of these solutions.

L10.5 Promotion of measures aimed at providing advice, the organisation of training and information sessions, the identification of funding opportunities, and the incubation of project proposals and their presentation to European R & D & I funding programmes.

L10.6 Support for PEB patent generation and exploitation in the construction sector.

Lines and axes of intervention.

L11. Specific means of boosting PEBs in vulnerable groups

Regulations should be developed to support the transition towards low carbon urban environments, instead of hindering climate neutral activities. The EU and national level are very important in the context of financing and developing building codes and standards. Therefore, it is important that local and regional governments have opportunities to advocate their positions to ensure that national guidelines and requirements are implementable on the ground. Here, city and regional networks, as well as EU- and national consultation processes and engagement in international projects can be very useful.

L11.1 Inclusion of the PEB concept in the energy efficiency targets on national level regulations for a larger introduction of PEBs.

L11.2 At regional and local level, visions for sustainability usually focus on broader concepts and there is often no specific interest in PEBs or the building level. When urban and regional energy and climate visions are wisely formulated, they can serve to enable and make PEBs attractive. In this sense, the following learnings and recommendations can be outlined:

- Set long term local and/or regional targets for spatial planning, energy efficiency improvements, RES utilisation and reducing of greenhouse gas emissions, while keeping goals as simple as possible.
- Choosing the essential guiding indicator(s) and give sufficient flexibility regarding the detailed design and technology choices to the stakeholders in new building or renovation projects.
- Regulating the crucial elements but try to avoid complex and overlapping regulation. Check both on mandatory regulations as well as complementing voluntary and/or incentive schemes. This will require mapping and analysing regulatory frameworks as well as other relevant schemes at all levels of governance.
- Transforming high level targets for carbon neutrality into practical steps and initiatives.

Lines and axes of intervention.

L11.3 Development of specific regulatory measures aimed at promoting PEBs, enabling a consistent (across various policy levels), stable and clear regulatory framework. As an example, this is the case of allowing a greater surface area if a building is reaching a PEB performance. Special attention should be given to most common technologies in PEBs, such as the installation of PV as far as possible integrated in the building and thermal energy storage.

L11.4 The life-cycle effects should be made mandatory in the planning phase.

L11.5 Regulatory measures to facilitate the interconnection of PEBs with local thermal and electrical grids.

L11.6 Regulatory measures associated with streamlining and reducing administrative formalities for the implementation of PEBs-associated projects.

L11.7 Enhancement of PEBs Observatories as a diagnostic and monitoring tool for rehabilitative action.

L11.8 Development of a code of good practice in the field of urban planning and building development to serve as the basis for local public administrations and private subjects, and which will serve as a reference for the drafting of all local legislation that has an impact on the matter.

L11.9 Development of an appropriate regulatory framework for local energy communities as a regulatory opportunity for PEBs: promoting pilots in these local communities to develop a business case for PEBs; maximising and increasing self-consumption through the sharing of energy surplus from PEBs.

L11.10 Embed PEB considerations into local planning frameworks. Some recommendations to consider PEBs in urban planning frameworks are the following:

- Translate the commitments and leadership for urban sustainability transition in medium to long-term urban development planning documents.
- Break goals down into milestones to underpin the levels of ambition of planning documents, programs and initiatives to be implemented on the ground.

Lines and axes of intervention.

- Link the plans to robust monitoring frameworks.
- Explore possibilities for integrated planning, such as grid-to-building interactions, the impact of electric vehicles, and climate adaptation and mitigation synergies or conflicts (i.e. greening roofs to reduce heat island effects vs. the greater roll-out of solar panels).
- Optimise solar access in urban layout.
- Aim for comfortable urban microclimate.

In concrete, relating to development plans at neighbourhood / district level, the recommendations are the following:

- Neighbourhood and district plans allow for the greatest incorporation of PEB development at local level, to be sure to include the sustainable development principles at their core in these plans from the beginning.
- Provide information and authority on optimal solutions, e.g. for building orientation or RES integration in the spatial plan or the lot release terms.
- Particularly when new districts are being developed on government-owned land, cities should mandate very detailed minimum sustainability requirements.
- As is the case with all plan-making, it is critical that stakeholders are engaged throughout the process, to gauge the technical and financial feasibility, social and environmental impacts as well as to create awareness and a sense of ownership.
- Start discussing and collaborating with local stakeholders early in the process, including energy system operators, energy producers, grid operators, load balancing aggregators, etc.
- Before implementing anything on a wider scale, define the basics clearly, including the definitions and technical requirements for a plus-energy building and the cost of these requirements.

8.Conclusions.

Buildings are responsible for approximately 40% of EU energy consumption and 36% of the energy-related greenhouse gas emissions. Buildings are therefore the greatest single energy consumer in Europe. Heating, cooling and domestic hot water account for 80% of the energy that we, the citizens, consume.

At present, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient. At the same time, only about 1% of the building stock is renewed each year.

The building sector is crucial for achieving the EU's energy and environmental goals. At the same time, better and more energy efficient buildings will improve the quality of life of citizens and alleviate energy poverty while bringing additional benefits, such as health and better indoor comfort levels, green jobs, to the economy and the society.

Both the construction and refurbishment of buildings in Europe needs to promote new models of **sustainable construction** oriented towards Positive Energy Buildings (PEBs) given their multiple advantages at environmental, economic, and social cohesion level.

The promotion of PEBs from a building, district, city and regional level should be conceived as one of the pillars on which a new, more sustainable construction model is based, aligned with the objectives of the European directives on energy efficiency, renewable energy and waste treatment.

To this end, the Policy Roadmap has been elaborated to facilitate the upscaling and replication of PEBs concepts, providing national/regional and local authorities with guidelines for the transition from the current construction model to a sustainable one, in economic, social and environmental terms.

The actions proposed in this Roadmap attempt to address the main barriers, through concrete measures whose formulation has been made possible thanks to the knowledge gained from the studies carried out in the different work packages during the EXCESS project and the 4 demo sites implemented, as important testbeds for different analyses.

Conclusions.

The strategic lines and axes of intervention include measures associated with regulatory, financial, economic and social factors.

Concerning the regulatory aspects, there is currently a broad regulatory framework, emanating from regional, national and European bodies, responsible for setting certain objectives and obligations in the field of energy efficiency in buildings. However, it is necessary to implement an appropriate complementary system of actions, which would allow to significantly increase the activity in PEBs, as the demand to adapt buildings to this concept that can lead to significant savings, in addition to adequate feedback for the implementation of subsequent programmes.

In relation to the economic aspects, it should be considered that a change from NZEB to PEB leads to higher investment costs and global costs according to the analysis of the EXCESS pilot cases mentioned before. To support the realisation of PEBs, either subsidies or new financial instruments are needed to cover the additional costs that cannot be covered by energy cost savings or costs of greenhouse gas emissions must increase to make energy cost savings more profitable.

Also, more clarity should be gained on the values of flexibility provision of PEBs as the related revenues could further reduce costs. If PEBs and PEDs should provide benefits to the overall energy system, incentives or tariff structures should be provided to keep self-sufficiency levels high across the entire year. Additional criteria for obtaining funds, such as social criteria for low -income citizens next to the above-mentioned sustainability criteria may play an increasing role in mainstreaming the PED concept.

Boosting new business models around PEBs, the training of new actors and applications around PEBs and measures to promote innovation around PEBs solutions at European, local and regional level are elements to be considered.

The public administration also has a major role in the promotion of PEBs. A strategic decision at regional/local level could be to achieve PEBs in all owned buildings where it is an economically justifiable choice.

Pilots, especially driven by public actors, are also a good way to promote PEBs. Transforming or developing new buildings owned by local or regional authorities to a PEB standard is a high-impact way to raise awareness, demonstrating leadership and move towards the decarbonisation of the public sector.

Conclusions.

Finally, regarding the social factors, creating awareness/reputation and demand for PEBs, as well as providing information and support in various ways, is a key element.

Often the investment costs are considered when making the decisions. So, it would be important to explain the advantages and benefits of PEBs (e.g. long-term economic return on investment) and to quantify the value-added of PEBs to the end-user. The need for “just sustainability transitions”, which incorporates social issues, should also be highlighted.

In conclusion, 11 lines of action and 58 measures have been proposed in the present Policy Roadmap aiming to establish the basis for a regulatory and financial framework for PEBs, which facilitates their development, a better interrelationship between all its actors, promoting the innovation and a more sustainable social development, facilitating universal access to PEBs solutions.

Annex

Anexx 1. Findings from Demo Cases.

This annex presents the regulatory framework at the demo locations, concentrating on those aspects that are likely to prevent or encourage the introduction of PEBs and local renewable energy businesses. In each country the focus is on the regulations that are relevant to the demo case in that country.

Finland

The PEB solution developed for the Finnish demonstration in EXCESS is based on a highly energy-efficient building combined with a hybrid energy system. The hybrid energy system represents an innovative approach to modern energy challenges, offering numerous strengths and opportunities that set it apart from traditional systems. This system boasts lower energy consumption, reduced life cycle costs, and decreased carbon emissions while harnessing various energy sources through advanced digital controls. However, its complexity and the necessity for extensive expertise present notable weaknesses and potential threats, such as unpredictable electricity prices and maintenance availability.

In Finland, the legal system operates under a framework of national law that is the primary source of legal authority. However, local and regional regulations also play important roles, complementing and specifying national laws to address local needs and circumstances. While energy performance and fire safety provisions are regulated at a national level, specific construction provisions and soil drilling fall under the jurisdiction of the City of Helsinki.

Energy Performance

In Finland, energy performance regulations for buildings play a crucial role in ensuring sustainability, minimising energy consumption, and mitigating environmental impact. This overview presents key regulations governing energy performance in buildings within the Finnish context.

- **Minimum Requirements for Building Energy Performance**: Designers must ensure that new buildings comply with stringent energy performance standards. These standards include minimising energy loss and achieving efficiency in room temperature, energy consumption, and ventilation systems.

Annex 1. Findings from Demo Cases.

- **Calculated Consumption of Delivered Energy of Buildings**: Energy consumption encompasses heating, ventilation, cooling systems, auxiliary units, consumer equipment, and lighting, minus any energy from environmental sources used within the building.
- **Net Heating Energy Demand:** The net heating energy demand for building spaces is calculated considering conduction loss, leakage air heat loss, and internal thermal loads.

Various other provisions address specific aspects of building energy performance, including building airtightness, ground frost insulation, calculated room temperature for the summer season, specific fan power of mechanical ventilation systems, and the building's heating capacity and electrical power demand.

Environmental Regulations

Deep Geothermal Drilling: All construction projects and changes to them that are likely to have significant environmental impacts must comply with the provisions under the Act on the Environmental Impact Assessment Procedure.

In addition to the latter and the Land Use and Building Act, the provisions stated in the City of Helsinki building regulations must be complied with. While constructing underground, it must be ensured that construction will not impact the safety of the existing above- and underground structures. Drilling a hole for a geothermal heat pump must not damage underground district heating, water, sewage, and other tunnels, pipes, or cables, nor any rock-covered facilities, such as cable tunnels, air-raid shelters, or parking garages.

Construction Regulations

The construction regulations in the City of Helsinki ensure that buildings harmonise with their surroundings, preserve environmental integrity, and adhere to legal requirements.

Harmonising with Surroundings: The surrounding environment and historical layers of the built environment must be considered to ensure that buildings form a harmonious ensemble with the urban image and natural values of the area.

Surface Level Maps: Building permits require a surface-level map to show existing height relationships. Lighting must enhance safety without disturbing residents.

Annex 1. Findings from Demo Cases.

Shoreline Regulations: Buildings must be at least 20 metres from shorelines, preserving vegetation, topography, and cultural values, with particular attention to external noise mitigation.

Building Permits: According to Section 125 of the Land Use and Building Act, a building permit is required to construct a building. This permit ensures compliance with all relevant regulations, including those related to energy performance, fire safety, and construction standards.

The potential and challenges of implementing hybrid energy systems are present in the following SWOT analysis:

Strengths	Weaknesses
♦ Lower yearly energy consumption of a hybrid system compared to a traditional one. ♦ Lower life cycle total costs. ♦ Lower carbon emissions. ♦ Hybrid system enables the use of various sources: excess heat from ventilation cooling, excess heat of PVTs, and geothermal heat from energy Wells. ♦ Intelligent control system: the digital system enables modifications later when a new system version is developed. ♦ Self-production by PVs.	♦ Complex hydronic system; the entire system requires high expertise. ♦ Massive amount of sensors and possibilities of sensor failures. ♦ A lot of initial/basic adjustments of the hydronic heating network. ♦ Long hydronic lines cause uncontrolled heat losses.
Opportunities	**Threats**
♦ Having access to the cheapest energy source possible. ♦ Possibilities for new control strategies implemented later: version management/updates for software. ♦ Service fee for the service provider.	♦ Availability of maintenance and service; Lack of service provider. ♦ Uncontrolled/unpredictable electricity prices.

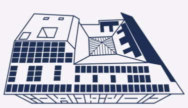
Annex 1. Findings from Demo Cases.

Recommendations

To accelerate energy efficiency, RES integration, and PEB roll-out, as well as financial incentives such as subsidies and grants, local governments could make PEB retrofits more attractive in various ways:

- Due to the high complexity and lack of expertise required, lighthouse projects or programs should be created for the private sector to develop expertise and gain skills in the practice of complex hydronic systems. Local governments could strengthen those by offering tender projects on public buildings, such as libraries and public schools.

- In addition to regional and national grant or subsidy schemes, local governments could consider establishing a special fund for PEB support and acting as guarantors for banks to offer low-interest loans for PEB projects. Furthermore, LGs should establish support mechanisms to facilitate energy efficiency access to the market via energy communities.



Spain

Article 15 of the Spanish Technical Building Code of Energy Savings (DB-HE) sets out the basic rules for making buildings more energy-efficient in the Spanish territory. These regulations are designed to promote a rational use of energy, reduce consumption to sustainable levels, and encourage the use of renewable energy sources. They include limitations on energy consumption based on location and building use, requirements for thermal envelope characteristics, specifications for thermal and lighting installations, and mandates for the use of renewable energy for hot water and electricity generation.

The provisions in this code are introductory and correspond to the competences attributed to the State in the Spanish Constitution. They must be further complemented with provisions from the regional building codes for their implementation.

Furthermore, the autonomous community of Castilla y León, where the DEMO is located, must promote sustainable mobility and urban proximity, as well as facilitate the improvement of energy efficiency while fomenting the use of renewable energy systems, creating the framework for this renovation work to be carried out.

Annex 1. Findings from Demo Cases.

In addition, the Urban Planning Law of Castilla y León highlights the objective of preventing contamination while fomenting public transport, sustainable mobility, and energy efficiency. Also, in its Article 36, the law establishes that when renovating a building, the latter must implement interventions that reduce energy demand, condition that is fulfilled by renovation works focused on transforming nearly-zero energy buildings into PEBs.

The renovation of protected buildings provides a clear value proposition. The main aspects are an enhanced property value, increased comfort as well as reduced electricity costs and revenues from renewable energy production. The multiple benefits of a PEB have to be emphasised and as far as possible economised building on lower energy costs, potential flexibility revenues, etc.

Strengths	Weaknesses
♦ In most of the cases, only energy refurbishment necessary. ♦ High replication potential.	♦ Need to engage all current inhabitants in PEB. ♦ They need to have an alternative accommodation to do part of the works.
Opportunities	**Threats**
♦ Transformation of heritage buildings into PEB. More similar heritage buildings in Valladolid could follow.	♦ Local regulations can put obstacles in the place-ments of the PV and heat pumps exterior units.

PEBs generate more energy than they consume, offering significant environmental, economic, and social benefits. However, renovation of a heritage protected building to PEB standard requires significant higher upfront investment compared to conventional renovation projects. Additionally, it is also more challenging due to regulations that have to be considered. Thus, creating a Business Model for renovating a heritage-protected building into a Positive Energy Building involves addressing unique challenges and opportunities due to the heritage status while aiming to transform the building into an energy-positive structure in a cost effective way.

[1] Decree 22/2004, of 29 January, which approves the Urban Planning Law of Castilla y León. Article 81.

Annex 1. Findings from Demo Cases.

The heritage protection of the building leads to additional construction costs and makes it necessary to involve additional stakeholders in the process. National and regional governments are an important partner as they define the heritage protection policies.

Furthermore, the building owner should assess the feasibility of other financing opportunities that may facilitate the overall costs model for a PED upgrade. For the case of Valladolid, the following two options could be considered

- The autonomous government provides public subsidies for building renovations, covering up to 40% of the cost, but these are paid after the renovation works are finished.

- The owner community can sell the energy savings to energy utilities with the system of CAEs (Energy Savings Certificates), depending on offers, compensating part of the cost of the renovation. With the proposed interventions, the building could generate up to 40.000 CAEs with an estimated value of up to 8.000€.

These amounts are paid after the renovation, so the community will need a loan to start the work. For this, the ICO (Official Institute of Credit) has a financing line providing guarantees for the consecution of the renovation loan.

The owner's community could also benefit from creating an energy community with the surrounding buildings. They could sell the energy surplus to commercial, or offices located in these buildings, where energy consumption during the day is usually higher, obtaining a higher profit than if it is fed into the grid, especially in the summer months, since most homeowners in this season live in a second home outside the city.

Recommendations

To accelerate energy efficiency, maximise the integration and use of renewable energy sources, and roll-out PEBs through financial incentives such as subsidies and grants, local governments could make PEB retrofits more attractive in various ways.

Annex 1. Findings from Demo Cases.

Firstly, due to the heavy restrictions on PV panels, because of their disturbing appearance, local governments should generate lighthouse projects on public buildings with better visual panels disguised as tiles. Despite their high cost, putting a series of small public projects out to tender improves demand and helps create a local market, pushing the private sector to develop skills while reducing costs and creating market awareness.

In addition to regional and national grant or subsidy schemes, local governments could consider establishing a special fund for PEB support and/or acting as guarantors for banks to offer low-interest loans for PEB projects.

Lastly, local governments should enhance technical advisory services (One-Stop-Shops) so that building owners can approach public officers to support them with decision-making on which measures/subsidies/grants to apply for to enhance buildings' energy performance.

Belgium

At a national level, only fire resistance and energy performance are regulated. The clearest is the national legislation for fire safety, which is arranged in terms of risk classes related to fire-fighting equipment. The general objectives of the legislation determine the minimum conditions to be met by the design, construction, and layout of buildings to:

- prevent the birth, development, and spread of a fire;
- ensure the safety of persons;
- facilitate the intervention of the fire department.

A construction element's fire behaviour is appreciated according to its resistance to fire and the fire reaction of its constituent materials.

Contracts for the delivery of work, including the delivery of building works, are primarily governed by Articles 1787 and the subsequent articles of the Belgian Civil Code, together with the rules of general contract law.

The applicable energy performance requirements have set criteria for primary energy consumption, insulation level, ventilation rate, overheating, and technical installations.

Annex 1. Findings from Demo Cases.

These These requirements differ for new or renovated buildings and units depending on the function (residential, office, educational, other non-residential). A requirement regarding thermal bridges was introduced. The reduction in energy consumption linked to this reinforcement of requirements has been estimated by simulation to be 25%. The requirements as planned for 2021 were:

Building/Unit	Net Heating Requirement (NHR)	Primary Energy Consumption (PEC)
Residential	15 kWh/m².year or X kWh/m².year	$45 + \max(0 ; 30\text{-}7.5 * C)+15*\max(0 ; 192/V_{EPR}\text{-}1)$ kWh/m².year

At a local level, there are also a series of guidelines for spatial integration, architectural development, and living quality in residential construction projects.

Regarding PV systems, there are requirements to consider when installing larger PV or PVT installations (> 10kVA). The DSO needs to verify whether the local grid can support the new PV installation. This study is free of charge for installations up to 25 kVA. For larger installations, the fee can amount to 550 € per connection. This procedure can be initiated via a web form on the DSO website (www.fluvius.be).

PV installations larger than 30 kVA require grid disconnection protection according to the Synergrid technical requirements. The investment costs for a grid disconnection setup are approximately 5 to 10 k€ per unit.

In another line, in 2022, a framework for energy sharing was established in Flanders under the incentive of the European Clean Energy Package. This framework provides a legal basis for trade and energy sharing between stakeholders. The local DSO facilitates this by managing and sharing detailed energy consumption data. Energy transactions are evaluated on a 15-minute time basis. The following transactions are made possible:

- Multiple peer-to-peer trade.
- Energy sharing within a building.
- Energy sharing between buildings with the same owner.
- Energy sharing within a (renewable) energy community.

Annex 1. Findings from Demo Cases.

The most attractive solution is for social housing companies (SHCs) in the context of PEBs' energy sharing within the SHCs' patrimony. Moreover, PEBs can be considered the cornerstone of this setup.

Buildings with large PV installations can provide excess energy to buildings that still have a net electricity demand at that moment, such as a building without PV and with a central electrical heat pump consuming electricity from a building with excess PV energy.

According to the most recent 2023 numbers for Flanders, 756 projects are registered where energy is shared in one of the formats mentioned above. Approximately 50% of these projects share energy between buildings of the same owner.

Thorough insulation is essential for an energy-efficient building envelope to reach the PEB standard. For renovation projects, **NZEB** insulation levels should be considered a target; for built projects, this is already a requirement, according to EPBD. Therefore, PEB technologies should be considered first for more recent buildings that meet the EPBD requirements during construction.

The social housing company can rely on the Flemish climate fund or apply for specific subsidy schemes to implement energy efficiency schemes in social housing infrastructure. These schemes can be used for large and smaller renovation projects (e.g., heating system replacement and building envelope thermal performance improvement). In July 2023, a total resource volume of 70 M€ was available within the climate fund.

Photovoltaic panels are also applied more frequently in social houses. The Aster project (supported by the European Commission and the European Investment Bank) is accelerated using an appropriate split-incentive financing model. The social housing company invests in PV panels, and the tenants purchase PV energy from the social housing company at a reduced tariff. Excess electricity is sold to the market. This model can also be applied to other energy-efficient technologies.

Under the incentive of the Energy Performance of Buildings Directive, heat pumps are also becoming more widespread for new building projects, such as the replication case in Kuringen. The social housing company invests in energy-efficient technology, and the users benefit from the savings on their energy consumption. The social housing company receives a reduction in the real estate tax for energy-efficient dwellings. The social company also recovers part of the additional investment for centralised sustainable heating systems via the heat tariff.

Annex 1. Findings from Demo Cases.

Regarding the Belgium demo and the possibilities to replicate, it is worth mentioning that heat pumps can be applied both centrally and collectively in combination with a heating network or individually by placing a heat pump in every dwelling. There are important considerations to take into account when deciding on the most suitable concept.

Choosing between centralised and decentralised systems is not just a matter of economic feasibility, there are more aspects to be considered when comparing both options, the most important aspects are summarised in a SWOT analysis:

Strengths	Weaknesses
♦ Lower electricity prices. ♦ Easier maintenance. ♦ Future proof. ♦ More free space in dwellings. ♦ Valorisation potential of PV and PVT.	♦ More operational aspects to consider. ♦ EPBD requirements. ♦ More complex to include passive cooling.
Opportunities	**Threats**
♦ Stable heat tariffs for vulnerable tenants. ♦ Scalable and replicable concept. ♦ Controllability and flexibility .	♦ General knowledge and complexity. ♦ Increasing construction costs in general.

From a purely economic point of view, and considering geothermal heat pumps, the following rules of thumb can be derived from the cost assessments made for the EXCESS demo site:

- For multi-storey apartment blocks or building blocks with communal basement, the central heating concept becomes more cost effective than individual heating when the project includes more than 10 dwellings. For terraced or semi-detached single-family houses, collective heating becomes more cost effective than individual heating for projects with more than 35 dwellings.

Annex 1. Findings from Demo Cases.

Recommendations

To accelerate energy efficiency, RES integration, and PEB roll-out, as well as financial incentives such as subsidies and grants, local and regional governments could make PEB retrofits more attractive in various ways.

First, local and regional governments should establish support mechanisms to facilitate the market's access to energy efficiency through energy communities.

To encourage the building of PEBs, local planning should enable higher density and higher buildings and add them to the building plans for new and existing buildings.

In addition to regional and national grant or subsidy schemes, local governments could consider establishing a special fund for PEB support and/or acting as a guarantor for banks to offer low-interest loans for PEB projects.

In implementing energy renovations, local governments could also set up a fund to support low-income households and those at risk of energy poverty. When feasible, more flexible requirements regarding building energy performance systems should be introduced.

Lastly, local governments should enhance technical advisory services (One-Stop Shops) so that building owners can approach public officers to support them with decision-making on which measures/subsidies/grants to apply for to enhance buildings' energy performance.

Austria

The goal of the Austrian Federal Government is to achieve Austria's climate neutrality by 2040 at the latest. An important interim goal is to reduce greenhouse gas emissions by 3 million tonnes of CO2-eq by 2030. All sectors contribute to the complete decarbonisation of the energy system, with the building sector playing a central role. After all, about 27% of Austria's final energy consumption is used for the provision of space heating, hot water and cooling in buildings.

Regulatory policy

The Austrian Institute of Construction Engineering carried out the “National Plan”. This contains minimum energy performance requirements for buildings by EPBD.

Annex 1. Findings from Demo Cases.

In 2019, the new OIB Guideline 6 (OIB-RL 6) “Energy saving and heat protection” was published, where the definition of lowest energy buildings and the regulation of energy savings for both residential and non-residential buildings are contained. This guideline deals with heating and cooling demand and final energy demand related to space heating and DHW of new buildings or those which are under a deep renovation process.

Erneuerbare-Ausbau-Gesetz (Renewable Expansion Act)

The Austrian government has set itself an ambitious goal in its government program: 100 percent of electricity is to be generated from renewable energies by 2030. This is an important step for the energy turnaround and on the way to climate neutrality. This requires a good legal framework: this will be created by the “Erneuerbare-Ausbau-Gesetz” (EAG, Renewable Expansion Act), which is currently under review and should be implemented in 2021.

The EAG is the most important law in the energy sector for decades and creates new participation opportunities for citizens and companies. It will trigger up to 30 billion Euros in investments in Austria and at the same time save around 10 million tons of CO2.

Following public support schemes are suitable for the replication case:

- Heating system replacement (“Raus aus Öl und Gas”).
- Renovation bonus (“Sanierungsbonus”).
- Clean heating for everyone (“Sauber Heizen für Alle).
- Heating system replacement (“Raus aus Öl und Gas”).
- Heating optimisation for multi-storey residential buildings (“Heizungsoptimierung im mehrgeschossigen Wohnbau”).

Considering the Austrian demo case, it is worth mentioning that serial renovation with multi-functional facade elements lead to multiple benefits that can have an economic impact:

Lower heat energy demand: The deep renovation of the building significantly (~80%) reduces the heat energy demand and therefore heat energy cost. Heating system is changed from gas heating to geothermal heat pump.

Annex 1. Findings from Demo Cases.

Cost savings and price stability through a switch to renewable based supply for thermal energy: Typically, buildings required energy at temperature levels of up to 70°C for space heating and hot water. The new installed heat dissipation systems with wall heating decreases the required temperature level for space heating, enabling low overall operating temperatures. These low supply temperatures can be provided at high conversion efficiencies by the installed heat pump.

No floor heating system needed: The wall heating system of the multi-functional facade element replaces existing heat distribution systems with radiators and does not need a change to floor heating system, which is one of the main advantages of a renovation with the multi-functional facade element.

Non-intrusive renovation process: One central benefit is the non-intrusiveness of the renovation process. This means that tenants do not have to move out during the renovation process, as the multi-functional facade element is placed on the outside of the building. Renovation with multi-functional facade elements therefore saves the cost for relocation of tenants.

Speed of renovation: Another financial benefit of the serial renovation approach is the speed of renovation. As the facade elements are prefabricated, the renovation process outside is faster (around 50-60% saving of time) compared to conventional renovation processes.

PV production: The multi-functional facade element also contains a building integrated PV module that leads to additional revenues from electricity feed into the grid.

Flexibility revenues: Buildings with wall heating systems activate a high thermal mass and therefore have a high potential for heat energy demand shifting. Flexible demand shifting could lead to additional flexibility revenues.

Recommendations

The multi-functional facade element fits best for renovation projects of buildings with construction year 1970 to 1990 as those buildings mostly have plain walls with low insulation levels. Therefore, there is high replication potential in Austria and particular in Vienna as there are many suitable buildings from this period.

However, renovation with multi-functional facade elements to PEB level is a complex process that faces many barriers. Currently there are no dedicated support schemes for serial renovation of buildings with multi-functional facade elements.

Annex 1. Findings from Demo Cases.

There are also no support schemes available that target the holistic approach of PEBs but only separate support mechanisms for insulation and RES installation. Thus, new innovative support schemes for serial renovation to PEB standard could increase the replication potential.

Renovation with multi-functional facade elements and heat pumps lead to a higher complexity of the buildings energy system, which requires high skilled companies that could plan, build and operate the energy system. Therefore, important drivers for PEB replication can be facilitators, One-Stop-Shops or specialised integrators that help to overcome the complexity barrier of the complex buildings energy system of PEBs.

Finally, also more ambitious obligations (minimum performance requirements) and strict and effective transposition, implementation and enforcement of existing legislation could boost the replication of PEBs.

Annex 2. Cost optimal technological solutions for PEBs.

The cost-optimality analysis highlighted the technical feasibility of achieving the Positive Energy Building (PEB) targeted in different climate zones.

The demo buildings in Spain, Austria and Belgium can achieve technical PEB standard with different technology packages. The Finnish demo case comes close to the PEB standard but cannot fully achieve it. The two central reasons are the cold climate conditions and the shape of the building.

The analysis showed that not all PEB technologies are cost effective technologies that reduce global costs. According to the present analysis discussed in this report, renewable energy production with PV can be considered as cost-effective technology, as global costs decrease with an increase in PV area with current electricity prices (~0.2€/kWh) and electricity selling prices (~0.1€). The shape of the building is a crucial parameter for the cost-effective realisation of a PEB. If there is little space for conventional PV, BiPV and PVT are key technologies for PEBs. However, BiPV and PVT are also more expensive than conventional PV.

Electricity production with gas based micro-cogeneration units is inefficient and not cost effective as it increases net primary energy demand and global costs. This conclusion can be derived from the analysis of the Belgian pilot case.

The change from a gas heating system to a new heat pump system is cost effective as it reduces net primary energy demand and global costs. However, the profitability of such a change is very sensitive to electricity and gas prices. If it is assumed that gas prices will decrease below 0.1€, high investment costs for a new heating system with aerothermal or geothermal heat pump cannot be offset by energy cost savings.

Furthermore, it can be concluded that additional functionalities in the thermal heating system increase global costs, as outlined in the results for the Finnish demo. The analysis showed that a geothermal heat pump with traditional 300m boreholes leads to lower global costs than the innovative thermal system of the Finnish demo with 600m deep boreholes, thermal storage and cooling system. The latter however provides a seasonal storage and a high level of flexibility to the energy system.

The cost effectiveness of PVT panels is difficult to assess. PVT decreases net primary energy demand but increases global costs with current available costs of the pilot cases.

Annex 1. Cost optimal technological solutions for PEBs.

The main cost driver at this technology is the complex installation of the panels. Only if costs for installation are further reduced, PVT can be a cost-effective technology and compete with PV. PVT has a high advantage if the roof is too small to provide sufficient PV energy to the building. It should also be mentioned that PVT has other advantages that are not considered in the cost optimality analysis such as in the Finnish pilot case where it provides heat to be stored in the boreholes, and thereby thermally regenerate the bedrock that serves as seasonal storage. In applications with low-cooling demand in combination with a high heat energy demand and little available space for the collector, the PVT is highly relevant for the efficient functioning of the thermal system.

This example shows that it is necessary to have a system view on costs. Even if individual technologies may not be cost efficient, they can be enabling technologies making the entire system cost efficient. Our analyses also showed the role of installation cost as important part of some of the technologies assessed, such as PVT, where there amount at some 50% of the overall costs. Skilled installers and easy mounting systems may be able to reduce these cost elements to some extent.

Another example for the need of a systemic view on costs is the Austrian demo case that showed that a multifunctional facade element (wall heating, insulation, PV) as standalone technology is not yet a cost-effective technology for the realisation of a positive energy building with the current assumptions and calculation methodology. Additional benefits have to be taken into account (e.g. higher comfort, higher self-sufficiency and thus lower energy cost in the neighbourhood or potential flexibility revenues) to make the multifunctional facade elements more favourable and profitable than a typical deep renovation. Testing this technology in the Austrian demo however showed potentials for cost decreases and it is expected that the technology becomes competitive as it gets more mature.

The sensitivity analysis showed that all results are very sensitive to electricity prices and feed-in tariffs. With an electricity price of 0.4€, almost all analysed technologies turn into cost effective technologies that reduce global costs. Due to an expected further decline of levelled cost of electricity production, it is not expected that the market price of electricity increases to a level of 0.4€. Therefore, only cost of greenhouse gas emissions (CO_2 tax or emission certificates) can raise electricity prices to a level that makes PEB technologies profitable without dedicated subsidies. Some technologies such as Bifacial PV have more functions than just electricity generation but can substitute conventional construction materials such as concrete or glass.

Annex 2. Cost optimal technological solutions for PEBs.

Overall, it can be said that many technologies increase global costs with current electricity prices (0.2€/kWh). A change from NZEB to PEB leads to higher investment costs and global costs according to the analysis of the EXCESS pilot cases. To support the realisation of PEBs, either subsidies are needed to cover the additional costs that cannot be covered by energy cost savings or costs of greenhouse gas emissions increased to make energy cost savings more profitable. Also, more clarity should be gained on the values of flexibility provision of PEBs as the related revenues could further reduce costs. In particular if PEBs and PEDs should provide benefits to the overall energy system, incentives or tariff structures should be provided that keep self-sufficiency levels high across the entire year.

Annex 3. Supporting Schemes for PEB roll out.

An analysis of available funding alternatives for energy renovations and installation of renewable technology for all building types was carried out as part of the EXCESS project.

The report summarises the information about energy efficiency schemes that could be used for financing PEBs, as well as potential needs for developing them to better support the roll-out of PEBs. The report: a) presents the potential funding that is available for PEBs, especially for the type of buildings and technologies that we have in the demos and b) suggests which would be the most suitable funding sources for similar cases as in the four EXCESS demo projects. It is also relevant to look at what would be the most efficient technologies to use now, or what should be developed further to come to better results. This leads to the recommendations for the most suitable funding sources.

The work and its reporting started with a short introduction to the background on the benefits of energy efficiency and renewable energy sources, and the European level legal framework. Next, the financing schemes available for PEBs were analysed, starting with a short summary of general funding sources and the funding instruments available at European level. The work also included a review and analysis of the technical and economic evidence on potential of PEB solutions. A brief study was also performed of different ways of valuating energy efficiency and sustainability at large, as these are often intertwined in the rating tools, which may influence on the availability of funding.

The benefits of PEBs include those related to energy efficiency, but also those related to the use of renewable energy sources. Energy efficiency leads to the reduction of both energy costs, vulnerability to energy and fuel price spikes, as well as operating and maintenance costs. In addition, it decreases greenhouse gas emissions and dependence on imports. It may also reduce negative effects on health and environmental risks. Renewable energy can e.g. generate new sources of growth, increase incomes, create jobs and improve welfare.

The legislation sets the scene for the PEBs and also partly for the funding, as the funding instruments are usually structured for supporting the legal framework. The key instruments on European level are the Energy Performance of Buildings Directive (EPBD) introduced in 2002 and its revisions in 2010, 2018 and 2024. The EPBD sets the targets and minimum requirements for the energy efficiency of buildings and their systems. This was further supported by the Renovation Wave strategy, with priorities in tackling energy poverty and worst-performing buildings, renovation of public buildings, and decarbonisation of heating and cooling.

Annex 3. Supporting Schemes for PEB roll out.

The recast of the EPBD as part of the Fit-for-55 package sets new requirements for new buildings and renovation, targeting zero emissions starting from 2028. It also includes requirements to equip buildings with solar technology. Other elements in the EU-level legal framework that are relevant for PEBs include the Energy Efficiency Directive (EED) and the Renewable Energy Directive (RED), which were also revised as part of the Fit-for-55 package.

The RePowerEU communication package launched in 2022 includes several strategies, action plans and recommendations to increase the capacity of renewable energy in the European Union. The realisation and detailed planning of these EU-level targets, strategies and directives are mostly left for the individual Member States, so the practices and emphases may vary in the individual countries.

Regarding the technical potential, there is a large variety of concepts and methods associated with the energy efficiency potential of buildings. Research on machine learning and artificial intelligence methods for the energy efficiency of the building stock has become more widespread, particularly in recent years. Concepts such as Building Information Modelling (BIM), Building Automation and Advanced Energy Management Systems have been increasingly combined over the last year with the concept of energy efficiency of the building stock. Among the research areas, the one on the building envelope and materials is the subject of considerable interest by the scientific community.

Other sources of energy efficiency also include heat pumps, energy storage systems and integration with renewable energy sources, in particular with solar photovoltaic. The aspects that have gained less attention include life-cycle assessment in connection with building renovation, and the social impact of energy efficiency measures is most often limited to the reduction in energy bills and the alleviation of energy poverty, while less attention is paid to thermal comfort and the effects on occupant well-being.

Regarding the economic potential, from the analysis of the data available in DEEP platform (De-risk Energy Efficiency platform) related to the energy efficiency investments in 2557 projects, it seems that interventions on the HVAC system and on the building envelope, achieve the greatest annual energy cost savings but lead to higher Levelled Cost of Energy (LCOE). On the building envelope, the smallest avoidance costs (LCOE) are gained by shading measures, followed by insulation and efficiency of the building roof and vertical envelope. Regarding the building type, the greatest avoidance costs occur in the case of detached single-family dwellings, followed by office buildings. On the other end, the least avoidance costs occurred in projects addressing educational buildings and multi-family buildings with 1-4 storeys.

Annex 3. Supporting Schemes for PEB roll out.

There is evidence that energy efficiency and other environmental rating systems affect the value of the building, on increasing rate, although there are also studies not showing a very clear connection, and the effect still seems to be relatively modest. The existence of several rating tools and the way they use the data is creating some confusion, and also some mistrust on the rating systems, created by this confusion. International efforts are however put in standardisation of the different evaluation methods and increased data availability for comparison. Once a common understanding of the rating systems has been gained, these could be used for the development of the funding schemes, so that the more sustainable (and energy efficient) solutions would receive better funding terms than the less sustainable.

A plethora of funding instruments are available at European and national level. Some of the funding opportunities are common and similar for all the countries, such as own funds, loans or mortgages and crowdfunding. Most of the funding is offered for renovation. As a conclusion of the analysis, there are many different funding opportunities and schemes available for energy efficiency and renewable integration. The wide variety of schemes is actually creating challenges for the investors and house owners, as it is sometimes hard to find the right channel. Also, applying for funding from different providers may create challenges in the timing, as the decision making may have different lengths in different institutions.

From the point of view on PEBs, it is a major challenge that most of the funding schemes are meant for a certain technology. PEB solution can be achieved with different combinations of technologies, and it requires the use of several solutions to reach the PEB level. A more holistic approach incentivising technical systems or modular technology packages, such as being tested for prefabricated facades in Austria will be key to accelerating the implementation of PEB technologies.

This requires new ways of formulating the requirements for the funding, and potentially co-operation between the funding agencies. But also funding schemes that specifically target district level renovations may be of high importance. More holistic funding may require the consideration of new target groups, such as service providers, building renovation aggregators or energy communities. Finally, additional criteria for obtaining funds, such as social criteria for low-income citizens next to the above-mentioned sustainability criteria may play an increasing role to mainstream the PED concept.

Anexx 4. New Business Model for PEBs.

For the new business model for PEBs analysis, key technologies considered include centralised high efficiency heat pumps, Bifacial PV, PVT or prefabricated multifunctional facade elements. The mentioned technologies are more expensive than conventional technologies such as PV or air source heat pumps, both regarding the investment costs as well as life cycle costs.

Renewable energy production with PV can be considered as cost-effective technology, as global costs decrease with an increase in PV area with current electricity prices (~0.2€/kWh) and electricity selling prices (~0.1€/kWh). The shape of the building is a crucial parameter for the cost-effective realization of a PEB. If there is little space for conventional PV, BiPV and PVT are key technologies for PEBs.

Key to making more innovate solutions attractive is to consider their additional functionalities that can partly lead to new revenue streams. The analysis showed that a geothermal heat pump with traditional 300m boreholes leads to lower global costs than the innovative thermal system of the Finnish demo with 600m deep boreholes, cooling system and thermal storage. The latter however provides a seasonal storage and a high level of flexibility to the energy system.

The cost effectiveness of PVT panels is difficult to assess. PVT decreases net primary energy demand but increases global costs with current available PVT costs in the pilot cases, however PVT can be part of broader solutions such as in the Finnish pilot case where it provides heat to be stored in the boreholes and thereby thermally regenerate the bedrock that serves as seasonal storage. In applications with low cooling demand in combination with a high heat energy demand and little available space for the collector, PVT is highly relevant for the efficient functioning of the thermal system.

This example shows that it is necessary to have a system view on costs. Even if individual technologies may not be cost efficient, they can be enabling technologies that make the entire system more cost efficient.

Another example for the need of a systemic view on costs is the Austrian demo case that showed that a multifunctional facade element (wall heating, insulation, PV) as standalone technology is not yet a cost-effective technology for the realisation of a positive energy building with the current assumptions and calculation methodology.

Anexx 4. New Business Model for PEBs.

Additional benefits have to be taken into account (e.g. higher on-site self-sufficiency rate and thus lower energy cost in the neighbourhood or potential flexibility revenues). This could make the multifunctional facade elements more favourable and profitable than a typical deep renovation.

The analysis also illustrated the important role of installation costs for some of the technologies that were assessed. For example, PVT installation costs amount to some 50% of the overall costs. Skilled installers and easy mounting systems may be able to reduce these cost elements.

Another example where more expensive technologies have more functions than just electricity generation is BIPV that can substitute conventional construction materials such as concrete or glass.

Also, the climatic conditions are critical for the economic performance of technologies, such as for thermal systems. The analysis also revealed that there are situations, especially in Southern Europe, where the PEB standard can be reached just with PV and without deep renovation measures as the PEB definition and the cost optimal framework do not distinguish between demand-side solutions (e.g. building envelope renovation) and RES-based active technologies and account over one year.

Furthermore, the PEB definitions and the cost optimal analysis also do not explicitly consider seasonal minimum self-sufficiency rates in the calculation method which grades down all technologies that provide seasonal storage.

It is recommended to solve such shortcomings with future revisions of European legislation and strategies (e.g. EPBD, EU cost optimal framework). In particular if PEBs and PEDs should provide benefits to the overall energy system, incentives or tariff structures should be provided that keep self-sufficiency levels high across the entire year.

Other additional benefits of PEBs that are not considered in the cost optimal methodology, as for example increased comfort through cooling and ventilation, should get higher attention as they may increase the value of properties. A change from NZEB to PEB standard leads to higher investment costs and in most cases also to higher global costs according to the analysis of the EXCESS pilot cases. To support the realisation of PEBs, either subsidies are needed to cover the additional costs that cannot be covered by energy cost savings or a pricing of greenhouse gas emissions to make energy cost savings more profitable.

Anexx 4. New Business Model for PEBs.

Also, more clarity should be gained on the values of flexibility provision of PEBs as the related revenues could further reduce global costs.

Key to finding viable business models is also to optimally use the onsite technologies within the building and neighbourhood. Provisions for energy and flexibility sharing therefore are key.

Finally, to implement PEBs, interests of stakeholders need to be aligned, with construction companies aiming for a low CAPEX, housing associations for a low OPEX, and energy suppliers preferring conventional technologies. A mix of policy requirements and incentives has to initiate a suitable value chain.

Annex 5. Database for buildings stock and indicators.

There are many databases for building stock in addition to the ones used by EXCESS. In this Annex we list the most interesting ones according to the EAB for the objectives of scaling the PEB concept. First, the EU buildings database includes information about almost-zero energy building allowing to know more about already energy efficient buildings. The TABULA from EPISCOPE is also a very useful resource for building level analysis and its functionalities could be expended and/or developed further. For energy consumption in dwellings and more general socio-economic information, Eurostat is indicated as the data source.

There are many other tools at national and regional level — in this case Flemish, Belgian databases. The Urban Energy Pathfinder developed by VITO is used by municipalities to assess renovation potential taking into account the building year, EPC label etc. The 'solar map' helps users assess the PV potential of buildings in Flanders, while the inspiration map — heat zoning supports the assessment on the potential for district heating systems and decides if a central or decentralise structure is better. Check Je huis [check your house] and Mijn Warm Huis [my warm house] are open-source tools developed by the city of Gent to promote energy efficiency, assess potential renovations, and support upscaling analysis. Finally, the website of the Flemish Energy and Climate Agency (VEKA) host useful information on energy performance certificates, EPC labels and energy projects e.g., solar, wind etc., registered within the system.

With Statistic Finland data on energy efficiency, type of heating, cost of the building could be found and used for different analysis. In Austria, city and national level databases were indicated: Statistic Austria and Statistic Vienna are helpful for specific questions such as age of building stock, renovations etc. In Portugal, an energy certificate database shows only the label but allows to check if in certain area buildings get renewed or not. The Romanian building ministry is currently working on a building database and at the governmental level a process has started.

Regarding the indicators included in the different database, the ones that are considered more relevant and offer useful information for the energy analysis of the buildings are:

- Indicators to pre-define the potential for **energy efficiency and generation**;
- **Building density**, in relation to all floors and the land plot;
- **Ownership** and **age** of the building to define strategy for renovation;

Annex 5. Database for buildings stock and indicators.

- **Socio-economic data** to inform engagement strategy. This could be done at the district level as more technology, the most suited engagement approach, depends on the context i.e., deprived or wealthy neighbourhoods.
- **Typology of building** i.e., 1 or 2 rooms, commercial etc.;
- **Energy comm**unity linked to the building and type of participation;
- Data on **energy consumption/produc**tion which, to be effective, could be not yearly or monthly, but every hour;
- **Quality of indoor environment**: temperature, CO_2 and other GHG emissions, humidity, light etc. It was highlighted that this could be used against a benchmark for the 'comfort zone';
- **Heating technologies** including boiler gas, oil, coal, wooden, pellets, solar etc.;
- **Energy storage devices** used within the building;
- **Energy usage** which, with a smart meter, would provide better data;
- **Air tightness**;
- **Envelope insulation**;
- **Material used**;
- **Energy performance certificates**;
- **Smart readiness indicators**;

As an indicator, the importance of a **user centric dimension is highlighted**: the relationship and structure between tenant and owner is very important when designing building renovation, although the difficulties of 'occupant dependent indicators' for privacy reasons. Other social indicators are associated to energy poverty, wellness, health…

Other indicators associated with the ones included in the definition of the Smart readiness indicators are:

◊ **Demand-Response functionalities;**

◊ **Link to/with the grid** as EV chargers & ways to stabilise the grid are very important;

Annex 5. Database for buildings stock and indicators.

Other indicators related to financial data or:

- **Cost**
- **Pay-back period;**
- **Insurance fees;**

Climate zone is also important as some technological solutions may not have economic sense in certain regions and/or climate zones.

Similarly, the **shape of the building** e.g., PVT is good if the surface is big and flat while a multifunctional facade needs large and even surfaces.