Lessons learned to inform integrated approaches for the renovation and modernisation of the built environment

Final report

ENER/C3/2019-468/03

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EXECUTIVE SUMMARY

A better performing and smarter building stock is the cornerstone of the EU decarbonised energy system. In addition to the vast energy saving potential, the building sector has the potential to provide flexibility to the energy system, through energy production, control, storage and demand response, as well as green charging stations for electric vehicles. At the same time, buildings can contribute to healthier living and wellbeing through improved indoor environmental quality (IEQ) but also as an integral part of green infrastructure and a sustainable and decarbonised built environment, contributing to social cohesion, climate adaptation and resource efficiency.

This study provides lessons learned from existing legal and non-legal policy instruments in 15 European Member States, 3 non-EU countries and 5 European regions.1 It formulates possible ways forward in informing integrated approaches for the renovation and modernisation of the building stock and the built environment. The study provides an understanding of how provisions within seven strategic areas and their interaction can be designed and amended to meet the European Union's long-term target to be climate-neutral by 2050 while maximising synergies and benefits. The following strategic areas have been analysed:

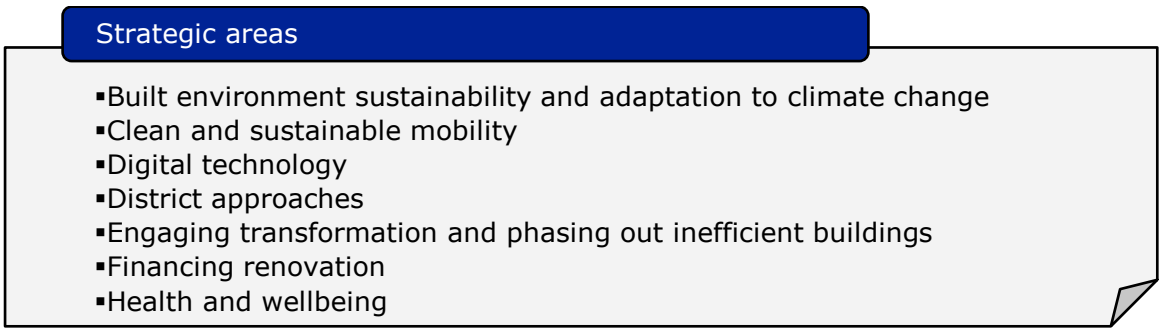

Figure 1: The seven strategic areas

Existing legal and non-legal policies and initiatives on multiple governance levels have been checked against their suitability to address key EU challenges of their respective strategic area (see Figure 2). The assessment of these policies and initiatives has confirmed that European Member States have implemented a wide variety of policy instruments addressing key EU challenges in the seven strategic areas. However, the efforts are neither sufficiently ambitious nor always coordinated across strategic areas. While there are already European legislation and incentives in place, there is scope for improvement in terms of implementation and better coordination across strategic areas at the national and sub-national level.

Policies and actions at the EU level alone cannot address all remaining problems adequately. Implementation takes place in the Member States, both on a national and subnational level such as through regions, districts, municipalities and, by extension, by all stakeholders involved in the renovation journey, including building owners. Cities are important levels of aggregation of demand, which has a direct impact on scale, risk and economies of scale. Concerted and coordination actions are needed from a variety of actors, including the construction industry, suppliers, energy advisors, financing institutions and social housing companies.

[1] EU Member States: BE, DE, DK, EL, ES, FR, HR, IR, IT, LT, NL, PO, PT, RO and SE. Non-EU countries: NO, UK, USA. European regions: Andalusia (Spain), Baden-Württemberg (Germany), Tirol (Austria), Silesia (Poland), and Umeå (Sweden)

	STRATEGIC AREA						
	Clean and sustainable mobility	**Digital technology for energy efficiency and renovation**	**Financing renovation**	**Health and wellbeing**	**District approach**	**Engaging transformation**	**Built environment**
1.	Creating a sustainable city layout	Unleashing the flexibility potential of energy uses via digitalised energy-consuming appliances and services	Unlocking financing renovation to end-users	Integrating health, wellbeing and comfort aspects in legislation and policy instruments associated with renovations	Developing integrated approaches maximising the synergies between energy efficiency and renewable energy at the district level	Creating an enabling framework for deep renovations that are not yet cost-effective	Designing sustainable buildings taking into account the lifecycle of materials
2.	Making buildings ready for e-mobility	Mainstreaming optimal energy uses via digitalised energy-consuming appliances and services	Financing building renovations in the presence of market failures	Enforcing existing provisions in support of indoor environmental quality	Streamlining and aggregating renovation solutions and processes at the neighbourhood level	Triggering acceptance and behavioural change of building owners and occupants about deep energy renovations	Fostering reuse and recycling of building materials and components
3.	Increasing joint investment in buildings and mobility	Digitalising the buildings renovation supply chain	Mobilising sustainable investments and de-risking energy efficiency investment	Quantifying health and wellbeing benefits from building renovations and integrating in the cost-optimal methodology to boost the renovation rate	Developing comprehensive (sub)urban strategies combining energy and carbon efficiency of the building stock with sustainable solutions	Accelerating the market penetration of innovative solutions for deep renovations	Applying technical adaptation measures that have limited negative side-effects
4.	-	Digitalising data collection of information about the building stock across Europe	-	-	-	Achieving deep energy renovations in a heterogeneous building stock with mixed ownership	Increasing awareness and implementation of nature-based solutions

Figure 2: Overview of challenges per strategic area

Lessons learned: 12 lessons to improve policies and initiatives with cross-area relevance

A series of lessons with cross-area relevance have been drawn from the analysis. Together with an analysis of good practices from all over Europe and more specific lessons per strategic area, they have informed the drafting of policy actions in the last part of the study.

Lesson learned 1: *Regulation and mandatory requirements are an indispensable part of the policy mix in most strategic areas*

Regulatory requirements are among the most promising policy instruments to effectively address the split-incentive dilemma – one major barrier towards deeper and faster energy renovation. However, different kinds of regulatory instruments and mandatory requirements are in place and they vary in their level of application. Also, minimum requirements for data collection, e.g., via energy performance certificates (EPCs), for urban planning, or for sustainable building design are impactful instruments and a precondition to set a more ambitious baseline for action at the Member State level.

Lesson learned 2: *Mandatory minimum energy performance standards (MEPS) play an important role in driving building renovation*

One specific part of this study (Annex IV) explores mandatory minimum energy performance requirements for existing buildings (here referred to as MEPS). MEPS are a regulatory requirement mandating buildings to meet a defined performance threshold, by a specified compliance date or according to natural trigger points in the building's lifecycle (e.g. time of sale). MEPS can apply to all buildings or particular building segments.

MEPS have already been implemented in various jurisdictions for this purpose, especially across Europe and the United States. For example, the UK, France, the Netherlands, and Belgium (Flanders and Brussels) have implemented, or have far-reaching plans to implement, MEPS for existing buildings. The common purposes of these regulations are to phase out the worst-performing buildings through renovations and to reduce energy poverty.

Annex IV presents a range of policy pathways outlining how MEPS can be supported and enforced by the EU. The pathway with the overall highest score of potential impact and feasibility suggests a binary implementation approach:

- For residential buildings, the policy action suggests the EU first introduce MEPS based on operational energy use (kWh/m²/year), to utilise the existing policy infrastructure, especially the current EPC schemes. MEPS should then evolve and consider the operational carbon performance (CO_2/m²/year) to align the requirement with the EU climate neutrality target. By combining the two metrics, it will be possible to ensure a minimum building performance level, which is essential to ensure a decent living standard for all Europeans, decarbonise the building stock and considerably increase resource efficiency, while the route to a "future-proof" building can optimise the balance between energy efficiency and renewable heating.[2]
- For non-residential buildings (alternatively, larger buildings), the policy action suggests real operational carbon is used to set the threshold. The carbon performance is derived from the actual energy consumption (e.g. as displayed

[2] Several existing EPCs already display the building's CO_2 footprint.

by smart meters) and the local energy mix, which is "normalised" based on the building's use, number of occupants, weather etc.[3]

MEPS have the potential to drive renovations when implemented effectively and with clear timelines. A progressively tightened requirement could help operationalise the objective of a highly efficient and decarbonised building stock by 2050.

Lesson learned 3: *There is further need for effective use of trigger points to enact deep energy renovation*

Trigger points are key moments in the life of a building (e.g. rental, sale, change of use, extension, repair or maintenance work) when carrying out energy renovations would be less disruptive and more economically advantageous than in other moments. Available funds often reach recipients who have a well-developed project in place. While the Energy Performance of Buildings Directive (EPBD) already emphasises the importance of trigger points to activate renovation beyond business-as-usual, country research shows that there is still room for strengthening the use of trigger points and to think of new points to trigger deep renovation. One example would be to define trigger points in improving accessibility for people with disabilities.[4] Work to upgrade a building to comply with accessibility provisions could serve as trigger points to assess and possibly deploy deep renovation options and vice versa.

Policymakers should consider opportunities and operational factors that facilitate the success of trigger points from a user's perspective and make sure that all relevant information is easily accessible, via independent advisers (including one-stop-shops) and suppliers. Equally, they should ensure that other existing requirements do not constitute a barrier to renovation (e.g. in multi-apartment buildings the decision to insulate the roof has to be taken by several homeowners and it may hinder deep renovation by limiting efficiency measures to individual apartments) and that e.g. financial support and permitting frameworks are agile and conducive to using trigger points.

Lesson learned 4: *A general lack of data must be addressed*

The lack of accessible and reliable data is a persisting challenge across all strategic areas. Existing databases, such as building registries and cadastres, EPC databases, material passports and the European Building Stock Observatory, differ in collection methodology, data specification and thus comparability, comprehensiveness, and accessibility. Besides the diversity of approaches, data protection concerns are inhibiting improvements in data collection. Better and more comprehensive data is needed to understand the energy performance and the overall condition of the EU building stock. This includes comprehensive and accessible data derived from EPCs, data on real-time energy consumption and according to monitoring and display, the share of renewable energy, carbon emissions, the lifecycle carbon impact of buildings, additional benefits and the smart-readiness of the building.

The private sector is the key enabler in this effort, as it already produces and gathers a large amount of building data. Data is, for example, created and gathered by the construction manufacturers, engineers, architects, construction workers, energy auditors, facility managers, utility companies and by the building owners themselves. Yet the fragmented approaches can only be solved through concerted efforts by the EU and the Member States, making sure the data is reliable, systematically collected,

[3] New York City's Law 97 sets annual carbon intensity limits on building emissions for larger buildings. See Annex 4 for more details.

[4] See for example, the European Accessibility Act, which is a directive that aims to improve the functioning of the internal market for accessible products and services, by removing barriers created by divergent rules in Member States.

shared, interoperable and used over the whole lifecycle of buildings. Also, data collection at the local level should be encouraged by providing financial support, technical assistance and capacity building to municipalities and supporting citizen science projects.

***Lesson learned 5**: Digital building logbooks can help fill the data gap*

A policy instrument that has gained cross-sectoral attention is the digital building logbook, which is a common repository for all building-related data[5]. For each strategic area, it serves slightly different purposes. Doing so, it can be a way of integrating different policy areas, by e.g. increasing the lifecycle perspective for new and existing buildings, informing planning by collecting and mapping data to better identify priority areas/districts for aggregated renovation projects, integrating mobility planning, integrating administrative information such as permits and requirements for compliance, or possibly including information on IEQ. The most reliable data is gathered by an energy expert via on-site visits, which comes with a considerable cost. On the other hand, on-site visits by experts have also been shown to be effective in encouraging the owner to invest in deeper and higher quality renovations.[6] Digital building logbooks can make sure experts have all possible information before visiting the building, which will optimise the required time on-site and thus also the related cost. Related to this, energy experts ought to be trained to have a more holistic understanding of the building compared to the performance of separate building elements and its interaction with the district and wider energy systems.

***Lesson learned 6:** Strengthening energy performance certificates could create multiple benefits*

In implementing the EPBD, EU Member States have established national EPC schemes. Improved and better-aligned EPCs could be beneficial to many strategic areas. They could include information on the carbon performance and provide information on renovation costs and thereby help to better capture trigger points. They could also be a dynamic data repository once digitalised, online and accessible, and prove compliance with policies (e.g. with mandatory minimum performance requirements; proof of eligibility for financial support, etc.).

***Lesson learned 7:** Urban planning is a promising way towards policy integration*

Urban planning is the obvious choice for the integration of different strategic areas (buildings, heating/electricity systems, sustainable mobility etc.). Planning takes place at different scales and should be used, among others, to prevent urban sprawl, operationalise aggregated renovation projects and integrate infrastructure for sustainable mobility. To unfold the planning potential, the EU should recommend the specification of minimum requirements in existing urban planning, e.g. for mobility plans to the extent possible through existing directives (e.g. Strategic Environmental Assessment (SEA) Directive[7]), or require the Member States to report on how they take certain aspects into account in their national and subnational planning tools. New planning principles such as the 15-minute city, the energy efficiency first principle and re-densification should systematically be implemented.

[5] The full definition of the digital building logbook is available in Volt, J & Toth, Z (2020) Definition of the digital building logbook. European Commission (Available: Online)

[6] See e.g. Fabbri M, et al. (2019) Technical study on the possible introduction of optional building renovation passports. European Commission. (Available: Online)

[7] Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (Available: Online)

Lesson learned 8: *New approaches need to become better known across sectors*

The country research revealed that while some policy concepts are well known at the European level and among scientific and academic stakeholders, many policy concepts need further explication and dissemination both vertically to national and subnational governance levels and across the sector. Among those are new ways of financing, such as on-bill or on-tax financing, project aggregation and renovation services that offer solutions via one-stop-shops, definition and meaning of nature-based solutions, a clear definition of a district approach, or benefits of deep energy renovation for health and well-being and on the importance of IEQ.

Lesson learned 9: *Financing remains a bottleneck for implementing a decarbonised and sustainable built environment*

Financing has been identified as a bottleneck in many strategic areas examined in this study. Innovative financing instruments need to become more widely deployed, which requires promotion campaigns, collaboration with local banks as well as innovation support for SMEs. In addition, new business models are required to facilitate the Renovation Wave, such as aggregation of renovation projects, the industrialisation of renovation, e.g. through the use of prefabricated systems for deep renovations, and the use of robotics and automatisation to optimise the process. Multiple opportunities for the construction value chain will arise, driving marginal improvement as well as larger disruptive innovations. Long-term financial support mechanisms, public and private, are needed to kick off the transformation and to ensure companies make the long-term capital investments (such as a factory to facilitate large production of prefabricated facades or HVAC)[8].

Lesson learned 10: *Available digital technology should be rolled out to enable promising approaches to support the creation of a sustainable built environment*

Digital technology development is advanced e.g. in reaping flexibility gains from the demand side, but it is not yet fully exploited for the creation of a sustainable built environment. For example, while BIM[9] is ready to be used in constructing new buildings, it is not yet mainstream in most markets, only a few solutions exist for the renovation of existing buildings and the cost for BIM remains a barrier in some markets. New opportunities to utilise digital innovations to decarbonise the existing building stock are still not fully explored, due to path-dependency or the remaining profitability of traditional practices. Better data collection and the use of digital solutions (e.g. making use of blockchain technology, digital building logbooks, or at least improved and web-accessible EPC databases) can steer the reorganisation and optimisation of construction and renovation processes. The availability of robust data enables new business models and better-targeted building renovation policies. Subsequently, building renovation could be organised along with priority areas, compliant with long-term targets and delivered at a faster pace.

Lesson learned 11: *Transparent communication and stakeholder interaction and engagement are critical success factors*

Across all strategic areas, transparent communication and stakeholder interaction and engagement help to build mutual trust and are key to enforce viable policy and technical

[8] See the experiences of the Energiesprong model, which is being developed in the Netherlands, France, Germany and Italy.

[9] BIM is a 3D model-oriented working process that allows multiple stakeholders and professionals to collaborate on the planning, design and construction of a building.

solutions.[10] This is especially relevant for urban planning but not restricted to this. There are several ways the EU is already promoting participatory approaches and communication. Besides supporting exchange and engagement by requiring participation processes, setting out guidelines or supporting networking, good practice exchange demonstrating the multiple benefits of building renovation could be an important driver.

Lesson learned 12: *Mobilisation of market-based approaches has been limited in existing policy mixes to date*

While there are examples of market-based approaches for building renovation and for the wider built environment, such as CO_2 price, the planned extension of the emissions trading system (ETS) to buildings and road transport, secondary material quotas, aggregate levies, or energy-saving obligation schemes, they currently do not play a major role in decarbonising the building stock. This may be due to the still-moderate targets and price levels found in existing cases (also driven by social acceptance constraints), although some instruments have delivered energy savings and greenhouse gas (GHG) emission reductions. Another plausible reason is that many of the barriers to renovation are non-economic barriers and can thus not be fixed with market-based approaches solely.

Conclusion

A range of policy instruments are best placed at the European level to facilitate learning and synergies between the Member States (e.g. when setting up novel instruments, like building renovation passports), to ensure a level playing field (e.g. carbon tax) and to secure comparability via harmonised approaches. The EU is best positioned to steer good practice exchange (e.g. on climate adaptation measures and sustainable mobility but also regarding innovative financing tools and lighthouse projects to alleviate energy poverty and implement future-proof districts) and support technical assistance.

Finally, it is important to better integrate instruments across policy areas to prevent loopholes and create consistency and coherence. This provides a stable framework for business models to rely on and allows for systemic transition as required to manage natural resources in a changing climate.

To build on these learnings and to tackle these cross-sectoral challenges and capture the opportunities, the study proposes the following policy cluster to be initiated at the EU level to improve the transition to a decarbonised building stock and sustainable built environment in 2050 (see Figure 3). The policy actions complement each other but could also be implemented as stand-alone measures.

[10] The Swedish city of Malmö has developed an "innovation platform", with the aim to foster collaboration around a more sustainable building stock. One example of the positive outcomes of this new approach is the urban regeneration of the rundown suburb of Lindängen in Malmö, where 14 administrations within the municipality were represented, together with regular workshops with researchers, property owners and stakeholders. The collaborative approach made sure that all relevant actors involved shared a common vision for the neighbourhood and the work. See BPIE (2018) Policy Innovation for Building Renovation. EIT Climate-KIC. (Available: Online)

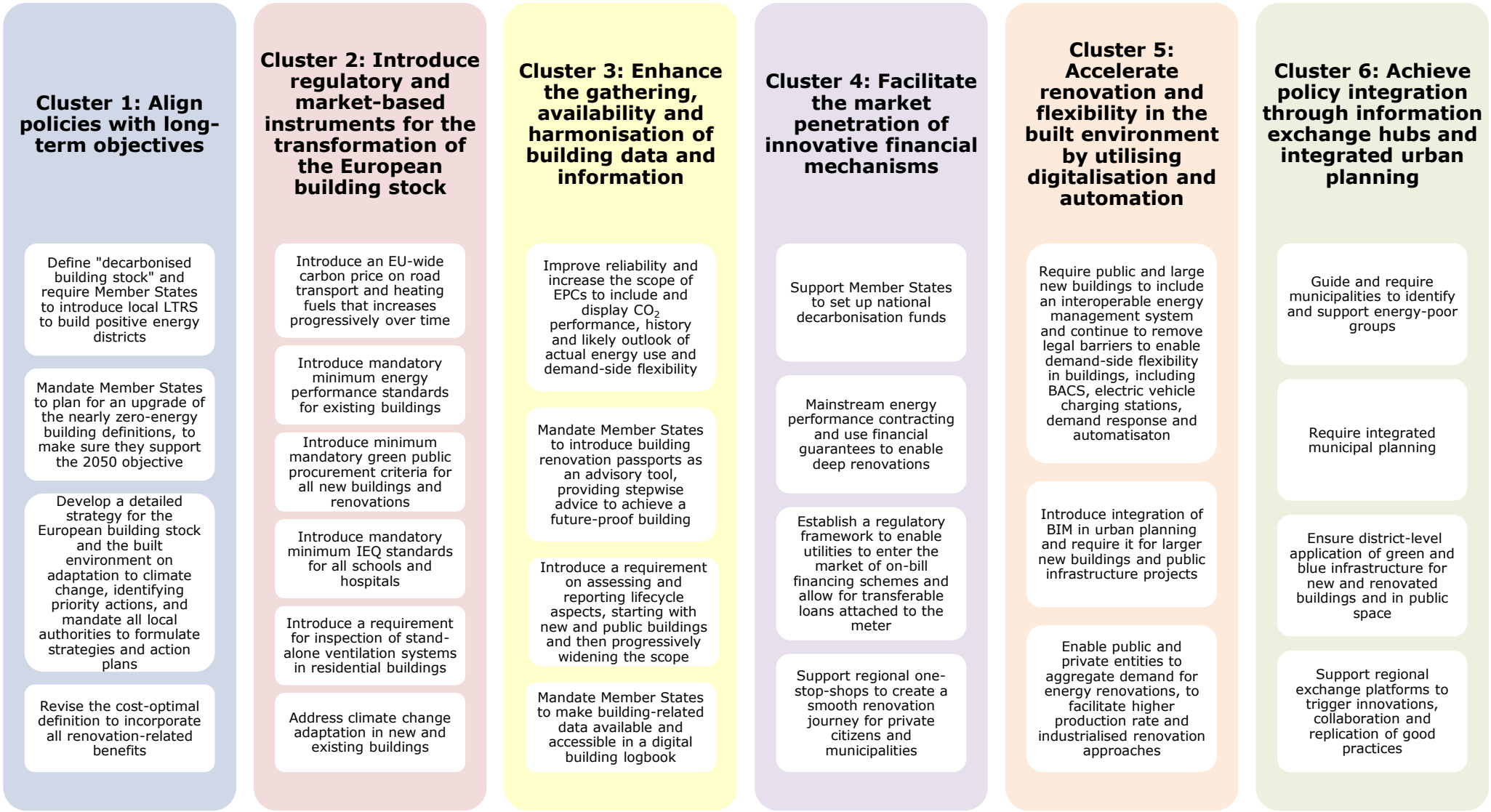

Figure 3: Identified policy actions

1. INTRODUCTION

A better performing and smarter building stock is the cornerstone of the EU decarbonised energy system. Buildings have the potential to provide flexibility to the energy system, through energy production, control, storage and demand response, as well as green charging stations for electric vehicles. At the same time, buildings can contribute to healthier living and wellbeing through improved indoor environmental quality (IEQ) but also as an integral part of green infrastructure and a sustainable and decarbonised built environment contributing to social cohesion, climate adaptation and resource protection.

This study provides lessons learned from existing legal and non-legal policy instruments in 15 European Member States, 3 non-EU countries and 5 European regions.[11] It formulates possible ways forward in informing integrated approaches for the renovation and modernisation of the building stock and the built environment. The study provides an understanding of how provisions within seven strategic areas and their interaction can be designed and amended to meet the European Union's long-term target to be climate-neutral by 2050 while maximising synergies and benefits. The following strategic areas have been analysed:

- Built environment sustainability and adaptation to climate change
- Clean and sustainable mobility
- Digital technology
- District approaches
- Engaging transformation and phasing out inefficient buildings
- Financing renovation
- Health and wellbeing

While the Energy Performance of Buildings Directive (EPBD) [Directive (EU) 2018/844] is the main legal reference, research activity within this study touches also upon other European directives, strategies, communications and initiatives.[12] The lessons learned below are also written in view of the strategy to scale up renovations entitled "A Renovation Wave for Europe – Greening our buildings, creating jobs, improving lives" (COM(2020)662) published on 14 October 2020. The European Commission reiterated its intention to revise the EPBD in 2021 and indicated the main elements this revision should contain in the Annex of the Renovation Wave strategy, indicating key actions and a timeline for the Commission. These elements are partly referred to in Chapter 3.2, which discusses how to align the policy actions with the outlined action plan.

This report presents the main lessons learned and the identified promising policy actions, which builds on the work done in the 4 previous tasks. It is the final outcome that builds on the research carried out throughout this year-long study, as well as stakeholder and expert input. The other outcomes, which substantiate and provide a background for what is presented in this report, are included as annexes. They are an integral part of the study and this final report.

Task 1

Task 1 sets out the definition of the main scope of the project, including screening the strategic areas and identifying gaps as well as key EU challenges within the seven strategic areas. It also presents the methodological approach to assess policy

[11] EU Member States: BE, DE, DK, EL, ES, FR, HR, IR, IT, LT, NL, PO, PT, RO and SE. Non-EU countries: NO, UK, and USA. European regions: Andalusia (Spain), Baden-Württemberg (Germany), Tirol (Austria), Silesia (Poland), and Umeå (Sweden).

[12] Annex I lists the documents that have been analysed for each strategic area to define the scope of the strategic areas underpinning this study. It further presents the scoping for each area and the identification of key EU challenges.

instruments and legislation for their ability to address identified challenges. The findings are presented in:

- *Annex I: Scoping and key challenges*

Tasks 2 and 3

The objective of these tasks is to provide a concise overview for at least seven strategic areas about how existing building codes and legislation may help to achieve the key EU challenges in this area. It also provides a concise overview of existing non-legislative building-related policy initiatives and standardisation activities that may help to address the key EU challenges in each of the identified strategic areas. The findings are presented in:

- *Annex II: Factsheets*
- *Annex III: Good practice examples*

Task 4

This semi-independent task presents an analysis of the scope, timeline and phasing of the progressive implementation of mandatory minimum requirements (MMR) in Europe, including the need for accompanying support policies. In this final report, MMR is referred to as mandatory minimum energy performance standards (i.e. MEPS), to align the wording with the Renovation Wave strategy. The findings are presented in:

- *Annex IV: Analysis of the relevance, feasibility and possible scope of mandatory minimum requirements for existing buildings*

2. LESSONS LEARNED: HOW TO OVERCOME THE MAIN CHALLENGES

In the following sections, the seven strategic areas will be introduced. The lessons learned as well as the assessment of policy actions are based on their ability to address the key challenges of each strategic area in section 2.2 as well as in Chapter 3, formulated below. A more detailed analysis of each strategic area and its key challenges is provided in Annex I.

This chapter also summarises the lessons learned from the country analysis per strategic area. It draws on the strategic area factsheets (Annex II), as well as the good practice examples (Annex III), which provide further detail and background analysis to this report.

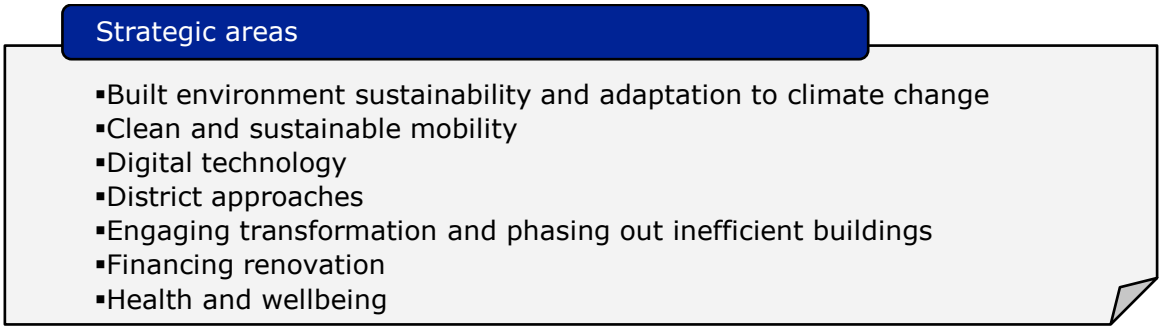

Figure 4: Seven strategic areas

2.1. Built environment sustainability and adaptation to climate change

Built environment sustainability

As the European building stock will undergo substantial renovation in the coming years, material use and embodied emissions are set to increase. Production of materials used for construction and construction processes make up a significant share of embodied energy for low-energy residential buildings.[13] Regarding lifecycle CO_2 emissions from EU buildings, materials and construction already account for 8-15%, and in countries with low-carbon energy and heating systems, the share and relative importance of materials and construction in lifecycle CO_2 emissions are increasing. For highly efficient buildings the upfront emissions often exceed 50%.[14] In a whole lifecycle approach, a low carbon building optimises the use of construction materials and limits carbon emissions during construction, use and end-of-life.

The level of circularity[15] depends on building design, material choice and composition, and transparent documentation of building parts. Additional circularity measures will also be key to keep embodied carbon emissions to a minimum, such as extending building lifetimes/ conservation, reducing construction and demolition waste, reusing structural building components, secondary material use and cement recycling.

[13] According to Chastas et al. (2017) Embodied energy and nearly zero energy buildings: A review in residential buildings (Available: Online), the embodied energy (i.e. energy used for manufacturing of materials, transportation, energy for the construction, maintenance, repair, replacement, energy for demolition and end-of-life management) is higher for low-energy than for conventional buildings, because the operating energy (i.e. energy used for cooling-ventilation, heating, lighting, hot water and auxiliary systems) is much lower in the former than in the latter. Hence, total lifecycle energy in conventional buildings is dominated by operating energy, whereas in low-carbon buildings embodied energy makes up the lion's share – approaching 100% in nearly zero-energy buildings.

[14] Ibid.

[15] Circularity here refers to construction and building systems in which resources are retained and reused, to minimise the carbon and environmental footprint of the sector.

Measures to increase circularity in the building sector could reduce emissions by 80 Mt CO_2 by 2050[16]. According to a recent EEA study, implementing circular economy actions in the building sector holds potential to reduce 61% of the GHG emissions across a building's lifecycle by 2050 compared to 2015.[17]-[18] Benefits from increasing circularity in the building sector for carbon savings also form part of the 'Circular Economy Principles for Building Design',[19] which the European Commission together with a wide set of stakeholders from the construction industry developed between 2016 and 2019. The principles encompass general and target group-specific approaches for increasing circularity in the building sector, which focus on fostering durability and adaptability of buildings as well as on reducing waste and facilitating high-quality waste management.

The following key challenges have been identified:

- Designing sustainable buildings taking into account their whole lifecycle
- Fostering reuse and recycling of building materials and components.

Lesson learned 1: *Material passports and digital building logbooks are promising tools enabling the design of sustainable buildings considering the lifecycle of materials*

The country research in this study has identified 29 relevant passports and logbooks. The analysed cases show a diversity of approaches, which aim to foster sustainable building design and promote a lifecycle perspective regarding the environmental impacts of materials used in construction.

Material passports and digital building logbooks can facilitate the reuse of building parts and deconstruction for recycling of construction materials and therefore foster a more circular built environment. Logbooks and material passports are considered very relevant digital repositories, which increase traceability and knowledge of construction materials used, as well as where and how they are embedded in building structures, thus enabling targeted repair and maintenance, reuse of components and obtaining secondary building materials, while excluding hazardous substances.[20]

Other relevant and more widespread approaches to increase transparency include standards, manuals and product declarations following lifecycle thinking, all of which ease public procurement and implementation of pilot projects. Some countries and regions have put in place legal acts and measures to promote lifecycle thinking and sustainability in the built environment, for instance in public procurement concerning buildings and construction (e.g. in Germany) or regarding the environmental performance of buildings (e.g. in Finland, the Netherlands, France, Sweden and London). Fulfilling these stipulations for lifecycle thinking around embodied carbon requires a systematic reporting on emissions linked to building design, construction, renovation and demolition processes and in building materials (production), so targeting the entire building lifecycle and thus transcending related value chains.

Planning for circularity and a long building lifetime when constructing new buildings is sometimes required by legislation, but more commonly encouraged by non-legislative approaches such as national plans or standards. For example, building information

[16] Material Economics (2018) The Circular Economy - a Powerful Force for Climate Mitigation. (Available: Online)
[17] European Environment Agency (2020) Cutting greenhouse gas emissions through the circular economy actions in the building sector. Briefing published on 09 July 2020. EEA, Copenhagen. (Available: Online).
[18] According to the recent study by UNEP IRP (2020), material efficiency strategies – which include circular economy actions such as substituting for renewable materials, lighter building structure, reuse, recycling – could yield significant savings in the material cycle of residential buildings by 2050: between 80 and 100% in G7 countries and China, and 50-70% in India.
[19] European Commission (2020) Circular economy – Principles for building design. (Available: Online).
[20] Hoibye, L. and Sand, H. (2018). Circular economy in the Nordic construction sector. Identification and assessment of potential policy instruments that can accelerate a transition toward a circular economy. TemaNord 2018:517. (Available: Online).

modelling (BIM) can be used to improve information flows in building projects. As setting up well-functioning BIM systems requires knowledge of materials, processes and technologies used during construction, this needs to start in the design phase and bring together stakeholders along the entire value chain.[21] With the aim of using public finances more efficiently, several Member States have put policies in place to simplify or require the use of BIM in public procurement, e.g. Denmark, Finland, Germany, Lithuania and the Netherlands. However, European industry players show only limited uptake of BIM, with almost two-thirds of construction companies never having used BIM. Those using BIM are mostly large companies with greater available human and economic capacities and working on large and complex projects, which make the benefits of using BIM more tangible. Furthermore, BIM is more widely used during the design and construction phase and hardly during operation, maintenance and renovations due to existing fragmented processes, little experience and associated costs of BIM.

Pilot projects for circular building design and reductions in resource use have been identified in several countries as relevant activities for the circular economy in buildings. They can inspire replication or the development of new pilot projects elsewhere.

National efforts to increase the market uptake of circular building design often feature improved information flows and transparency (for instance via BIM), as well as funding for research and development and pilot projects. However, legislative provisions also play a role towards mainstreaming sustainable building design, for instance when stipulating design for longevity and disassembly or via legislation on climate protection, which fosters the integration of lifecycle thinking for low-carbon materials.

Lesson learned 2: *Regulatory instruments foster reuse and recycling of building materials and components*

Country research shows a diversity of approaches aiming to foster reuse and recycling of building materials and components. Although differing in their approaches, the provisions identified as relevant do have in common the promotion of:

- Use of recycled content and of secondary raw materials in buildings
- Circularity in the renovation and reuse of existing buildings and construction products
- Reductions in the amount of construction waste.

Relevant approaches encompass national plans, legislation and standards that foster and stipulate the use of secondary materials in buildings, in many cases referring to environmental product declarations. Several countries have implemented provisions that foster the consideration of environmental criteria in public procurement, increasing the relevance of environmental information in procurement decisions. In sum, there is generally broad coverage of regulatory instruments, and increasing reuse of building materials and components fits with existing national and regional building or waste legislation.

Meanwhile, some countries apply approaches that discourage the use of primary construction minerals, e.g. via a charge on aggregate (sand, gravel and limestone) extraction in the UK (aggregates levy) or a prohibition on setting up a landfill for most construction and demolition waste in the Belgian region of Wallonia.

New routines and guidelines have been implemented to ease the reuse of building materials or components, for instance, pre-demolition inventories as recommended in the EU Construction and Demolition Waste Protocol and Guidelines. Furthermore,

[21] European Commission (2019a). European Construction Sector Observatory: Building information modelling in the EU construction sector. Trend Paper Series, March 2019. (Available: Website).

information and labelling also help to foster increased use of secondary materials in buildings. Involvement of all key players and engagement in dialogue is one of the key challenges. On the demand side, information flows, facilitated by credible labels and certification, enable owners and purchasers of buildings and building services to identify and opt for circular solutions.

Adaptation to climate change

Buildings are long-lasting assets that rarely undergo renovations. That is why when a retrofit takes place it should also make buildings more resilient to the effects of climate change. The main climate hazards buildings face include extreme precipitation, heatwaves, heavy snowfall and rising sea levels. These will affect buildings differently depending on their design and location. Adaptation solutions for buildings focus on technical measures such as shading devices, planning adjustments such as building design and orientation, and nature-based solutions such as green roofs, walls or facades, which can regulate temperature variability as well as buffer precipitation peaks. It should also be noted that technologies installed in buildings to reduce emissions can be vulnerable to climate impacts. For example, solar PV panels are vulnerable to extreme weather events such as hail and high-speed winds. It is worth assessing the possible impacts of climate change on these technologies and identifying adaptation options.

Climate impacts, especially due to extreme events e.g. storm, flooding, heatwaves, could be integrated into requirements for buildings and the built environment. Approaches should support increased climate resilience of buildings and define recommendations and requirements such as energy-efficient air conditioning and flood protection (e.g. check valves).

The following key EU challenges have been identified:

- Apply technical adaptation measures that have limited negative side effects
- Increase awareness and implementation of nature-based solutions.

Lesson learned 3: *Only a few countries support the implementation of technical adaptation measures*

Countries implemented diverse approaches to support the application of technical adaptation measures to increase the climate resilience of buildings. However, they are insufficient to tackle the challenge. Although differing in their approaches, the provisions identified as relevant have in common the promotion of:

- Using and collecting rainwater around buildings, e.g. by cisterns, tanks
- Implementing sun protection and shading on and in buildings
- Efficient water uses in and around buildings
- Protection against flooding and landslides
- Providing information and data on local climate impacts (e.g. flood risk) which can be used by municipalities to adjust local approaches.

Legislative approaches include grants/funding for the construction of rainwater collection, such as cisterns and tanks, and programmes to incentivise the implementation of sun protection and shading measures. Regulations are in place to avoid overheating of buildings, e.g. including technical guidelines. Technical regulations also concern protection against flooding and landslides, and ordinances and technical regulations are in place regarding water conservation and the use of water-efficient products within and around buildings.

Non-legislative measures include initiatives on providing and promoting information and data platforms highlighting local climate impacts, which can guide municipalities when designing legislative and non-legislative measures. Further information platforms are

promoting rainwater collection for private homes. Guidelines and support programmes have been established for climate-friendly construction, protection measures on buildings against extreme events, and passive houses including low energy use for cooling. Some building certification programmes include water efficiency as a performance indicator.

Some adaptation approaches are designed to reduce the negative side effects of these measures (e.g. additional energy use of active air conditioning), such as the promotion of passive houses that focus on passive ventilation, e.g. via information material.[22] Other promoted approaches do not cause significant side effects, such as rainwater collection. Equally, technical mitigation measures should not have an adverse effect on the building's resilience against climate change.

Lesson learned 4: *awareness-raising and implementation of nature-based solutions are mostly non-legislative*

Country research shows a diversity of approaches that aim to increase the awareness and implementation of nature-based solutions. Although differing in their approaches (legislative vs. non-legislative), the provisions identified as relevant do have in common the promotion of:

- Constructing green or 'productive' roofs, terraces or vertical walls
- Using ecological materials in work on the envelope of buildings
- Creating open and permeable surfaces to fight against flooding and support water management
- Research to increase the evidence base and create support for nature-based solutions.

Relevant legislative approaches encompass grants/subsidies for the construction of green or productive roofs, or terms, conditions and standards that foster and stipulate the use and planting of ecological materials in/on/around buildings.

Non-legislative measures, which were far more prevalent than legislative measures, include initiatives to encourage the introduction of sustainable architecture and permeable and vegetated surfaces in building renovations or reconstructions, foster citizen-led revegetation projects in public spaces, increase knowledge and evidence on nature-based solutions through research/pilot projects, and raise awareness of nature-based solutions as a tool e.g. reducing flood risks or sustainable urban development.

Lesson learned 5: *Mandatory technical regulations and building codes could be better used for implementing technical adaptation measures*

To reach the effective implementation and uptake of technical adaptation measures a sound mix of policies is essential. Looking at the negative side effects of technical adaptation measures, such as increasing GHG emissions due to the installation of cooling appliances and systems, well-designed policy responses are necessary. Mandatory technical regulations and building codes could have an essential impact on increasing climate resilience of buildings, including e.g. sun-shading, flood protection and water efficiency. They should include a focus on passive houses, passive cooling systems etc. to limit negative side effects of increasing energy use mainly due to active air conditioning. However, their application is not yet widespread across countries.

[22] An elaborated information brochure was developed by the city of Hamburg which, besides technical information, includes statements of residents describing their experiences (Freie und Hansestadt Hamburg, Behörde für Stadtentwicklung und Umwelt (2007) Leben im Passivhaus, komfortabel – kostengünstig – ökologisch. BSU, Hamburg).

Other aspects are difficult to include in technical regulations as they depend on the individual building location and local circumstances. An example is the adjustment of the building's site (e.g. windows, rooms) to certain cardinal directions. These adjustments can be an effective instrument to limit cooling demand but can only be reached by guidance and information for planning for architecture offices and housebuilders. Certification programmes and labels cover several environmental challenges such as water efficiency and reuse, energy efficiency and waste management. They can give positive incentives to include these aspects in building projects. Some examples show that certification and label systems can be included in local regulations and then become mandatory for new houses.

While reducing GHG emissions is not the main objective of technical adaptation measures, well-designed policies should limit the increase of GHG emissions linked to responses such as active cooling systems.

Due to weather events during recent years, adaptation policies are currently on the political agenda in many EU Member States, with adaptation strategies and actions plans being developed or adopted at national, regional and local levels. At the EU level, the processes linked to the EU adaptation strategy are ongoing; some encourage national adoption of technical regulation on climate-resilient buildings. Standards are not developed and adopted by public governments but by standardisation organisations (mainly at national or international level, e.g. ISO, DIN). The integration of adaptation therefore depends on awareness and interest within these organisations. CEN-CENELEC has already founded an 'Adaptation to Climate Change' coordination group, which coordinates standardisation activities and guides the implementation of the standardisation request on climate adaptation. To further increase awareness the topic could be included within national stakeholder and network activities organised by public authorities. In this regard, existing city networks such as Covenant of Mayors for Climate and Energy or Climate Alliance could be used to raise awareness and support exchange at local level.

Lessons learned 6: *The concept of nature-based solutions is still largely unknown*

The lack of measures for nature-based solutions in most regions/countries can be attributed to the fact that this term, largely adopted at EU level, is relatively new in the Member States and at the regional level. Nature-based solutions can be understood as actions to protect, sustainably manage and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human wellbeing and biodiversity benefits. Providing information and increasing awareness of nature-based solutions is a precondition to increase their local uptake, which could additionally be supported by financial programmes, grants, etc.

2.2. Clean and sustainable mobility

The transport sector is a large and still increasing source of GHG emissions and air pollutants. Car- and lorry-based mobility also has negative impacts on safety, space distribution and quality of life. Better urban design and planning can contribute to more sustainable transport options, including by helping to reduce car travel, shortening daily travel distances and ensuring that new settlements are public transport oriented. Building design can also facilitate more sustainable transportation by, for example, providing charging infrastructure for electric vehicles or bike parking, including for cargo bikes.

The EU approach to addressing transport's climate and environmental impacts is based on improving the efficiency of vehicles, using alternative fuels, and shifting to sustainable means of transport and new mobility patterns.

Urban planning is a competence typically assigned to regional and local authorities in virtually all Member States. National governments can influence outcomes to a varying

degree by setting out national principles or by providing funding, but most decisions are made at the sub-national level. Overall, most instruments identified in the mobility area at the national level are legislative measures, while on the regional and local level information-based measures, best-practice sharing and support through handbooks also play a key role.

The following key EU challenges have been identified:

- Creating sustainable city layouts
- Making buildings ready for e-mobility
- Increasing joint investment in buildings and mobility.

Lesson learned 7: *Creating sustainable city layouts can benefit from new planning principles*

Many countries have overarching plans for green urban planning enshrined in legislation. This includes provisions to reduce the need for transport and to increase the sustainability of each trip by promoting smart working, car sharing, the use of public transport and the adoption of efficient vehicles and alternative fuels. Other measures aiming to encourage inhabitants to move away from the private car include innovative principles for planning new neighbourhoods and parking space management.

While local authorities are central players in charge of planning processes, decisions require coordination with regional and in some cases national governments and with stakeholders, including private actors such as developers or transport operators. Moreover, urban planning for sustainable mobility has many dimensions and the importance of each dimension always depends on local conditions.

The "15-minute city" offers a new vision of a sustainable city layout. Its goal is that each resident can cover all basic needs with a bike or walking trip of 15 minutes or less. Basic needs include work, education, experiencing nature, shopping, leisure activities like sports, cultural events and social gathering, and medical care. The new planning paradigm has been taken up by the C40 Cities in their agenda for a green and just recovery from the Covid-19 pandemic. It could also guide district approaches and profit from a digital building logbook that include the built environment.

To promote cycling, some countries and local authorities are implementing very concrete regulations. These include examples of regulations requiring secure bike parking spots for new residential and commercial buildings. Some national and regional governments financially support cycling investments at the local level. Non-legislative measures include guides on local cycling action plans or best practice sharing between local authorities.

Lesson learned 8*: EU regulation has created a significant stimulus for making buildings ready for e-mobility*

Most countries have already implemented regulation mandated by the EPBD to install charging points in certain public parking spaces and to set pre-tubing requirements that allow for subsequent installation of charging points in new or renovated residential buildings of a certain size or are planning to do so.

The country analysis also shows that many national governments provide grants for private actors who install charging infrastructure in buildings and car parks or on streets. Other countries use tax rebates or soft loans to support the installation of privately owned charging infrastructure. An interesting legislative approach is using local cooperation agreements between the local government and private sector to ensure minimum and accessible charging infrastructure in business parks.

Many countries support the roll-out of charging infrastructure by clarifying technical and regulatory issues, e.g. relating to the roles of different actors and their interaction as well as rules on tariffs and safety regulations, enabling distribution grid operators to manage the impacts of electric mobility on grids and connection capacity. Finally, the Nordic countries have established the database NOBIL which provides a map of existing charging points and their accessibility, including those charging points in public and residential buildings.

Lesson learned 9: *Increased investments to redesign urban areas are not yet secured*

The country analysis shows that there are only a few financing instruments in place for the sustainable redesign of urban areas beyond fiscal incentives for electromobility charging infrastructure. This could point to a lack of suitable ideas on how to tackle this challenge. As the factsheet on district approaches shows, district- or neighbourhood-level projects have the potential to increase the attractiveness of investments thanks to project aggregation and distributed risk portfolios. The larger scope can enable new business models and financing solutions.

Among the few identified examples is a scheme co-funding municipalities for mobility projects that limit traffic and pollution, including cycling projects, walking initiatives, carpooling, car sharing, bike pooling, bike-sharing, education programmes and road safety and mobility management schemes at universities, schools or other public bodies as well as loans for smart city model projects.

Lesson learned 10: *A cross-sectoral approach to financing a sustainable built environment could also inspire clean mobility*

The country research shows that a variety of provisions exist that address urban planning and charging infrastructure for e-mobility. Broader financing measures for integrated urban mobility solutions (rather than instruments focusing on specific standalone investments such as charging points or cycling infrastructure) are less widespread and need to be further addressed. A cross-sectoral approach to tackle the challenge could create new ideas for a sustainable built environment and help harvest synergies (district approach, financing renovation, engaging transformation).

Overall, most instruments identified in the mobility area are legislative measures, while there are no/limited cross-sectoral approaches to financing clean mobility. This results from the research focus targeting primarily national-level action. On the regional and local level information-based measures, best-practice sharing and support through handbooks also play a key role.

Lesson learned 11: *Urban planning can be influenced by European and national actions but requires strong vertical and horizontal cooperation*

There is a high variation even within the Member States regarding the approaches to create a sustainable city layout. This is partly because urban planning is a competence assigned to regional and local authorities. As a result, national-level measures mostly have a supportive or guiding character while local authorities take the final decisions. Accordingly, some cities effectively tackle the sustainable mobility challenge and others neglect the issue.

The analysis nonetheless shows that ambitious national governments and regions aim to guide local action by developing overarching visions for sustainable urban areas and setting out key principles such as the need to mix functions, to ensure access to public transport, to reduce public space devoted to car traffic and to build attractive biking and walking infrastructure. New paradigms such as the vision of a 15-minute city can help to build the momentum for local action. Even though overarching visions cannot in and of themselves produce emissions reductions, they have a key function in communicating the goal of single measures and streamlining these towards a coherent strategy, some

aspects of which, like removing car parking spots, can be unpopular with parts of the electorate.

The most comprehensive approaches combine the overarching visions with concrete actions on the different dimensions, e.g. by providing financial support or mandating minimum bike parking spots to be provided at new or renovated buildings, or limiting the need for car parking spots in new buildings. These approaches tackle the problem of multi-level governance by recognising that effectiveness will require strong vertical and horizontal cooperation between national, regional and local governments and among neighbouring municipalities or regions.

Good practice examples include national or regional funding for local authorities to support them in an integrated planning exercise aimed at boosting sustainable transport. This can take the form of funding for integrated mobility plans or cycling strategies, or include good practice guides for local authorities on legal, financial and technical questions of implementation.

***Lesson learned 12**: Strategy and planning tools are crucial: the EU can formulate minimum requirements for mobility plans*

In the face of the given heterogeneity, strategy and planning tools appear particularly useful, because they can allow each country, region and municipality to assess its starting point and formulate steps forward from there. Ease of implementation will depend on internal capacity and knowledge about the issue in each administration. Since 2013, the EU is actively encouraging Member States to draw up sustainable urban mobility plans (SUMPs) which now exist in more than 1,000 EU towns and cities according to the ELTIS database. The SUMP principles include the need to define an overarching vision, to engage citizens in the process, to define implementation actions and to set up processes for evaluation.[23] The EU can build on this well-developed tool and implement measures to make its use even more widespread, e.g. by linking funding streams to the existence of high-quality SUMPs that are in line with EU climate targets and by increasing spending on capacity support and best practice exchange.

2.3. Digital technology for energy efficiency and renovation

Digital technologies can be used across the lifecycle of buildings, from design and construction to people using buildings. Digitalisation is a key enabler of the decarbonisation of the building stock. Firstly, it has great potential to increase the quality and scalability of energy efficiency solutions, with optimal design (for example, BIM, drones, digital collaboration platforms), execution (for example, additive manufacturing, prefabrication), and use of buildings (for example, automated management systems, controllable devices and smart appliances, data collection). Secondly, it gives building users smart and flexible energy services, allowing the development of demand-side management strategies that help further integrate variable and decentralised renewable energy sources into the energy system.

The following key challenges have been identified:

- Unleashing the flexibility potential of energy uses via digitalised energy-consuming appliances and services
- Mainstreaming optimal energy uses via digitalised energy-consuming appliances and services
- Digitalising the buildings renovation value chain
- Digitalising data collection of information about the building stock across Europe.

[23] European Platform on Sustainable Urban Mobility Plans (2019) Guidelines for developing and implementing a sustainable urban mobility plan. (Available: Online).

While there are promising examples of policies improving energy efficiency and renovation with the help of digital technology, they are far from being widespread across Europe. Looking across the provisions in place, we see that there are both:

- Comprehensive strategies which typically cover a much wider range of policies than just digitalisation of the construction and renovation sectors but include some of the elements required to support it.
- More specific programmes on digital technology in the construction and renovation value chain: a whole series of policies have been implemented across Europe, from regulations on smart meters and the self-consumption of electricity to the agreement on a smart and flexible energy system. Many countries are not covering sufficiently the more specific aspects related to the renovation of the building sector.

***Lesson learned 13**: There are solutions to digitalise the buildings renovation supply chain, but their application in practice is still low*

The whole construction ecosystem can benefit from digitalisation. Building information modelling (BIM) can help optimise the building's management to reduce the energy and overall resource consumption. Digitised construction processes and 3D scans are a precondition to achieve economies of scales in renovating larger projects making use of prefabricated building components. However, there are many barriers to the complete uptake of BIM and other digital solutions, including lack of investment, lack of trained employees, lack of software (often due to cost) or considerations on interoperability and data security. While countries generally support BIM, sometimes even requiring BIM for the construction of new public buildings, or are in the process of framing comprehensive action plans for BIM deployment, it is only slowly being taken up by the markets. According to the European Commission's Renovation Wave, 70% of construction firms dedicate less than 1% of their revenues to digital and innovative projects, and the uptake of BIM remains particularly low. In addition, there are only a couple of examples of grant programmes that are specifically supporting serial renovation practices and the general application of BIM for renovation remains to a large extent in the sphere of research and demonstration projects.

***Lesson learned 14:** The digitalised data collection of information about the building stock across Europe is not harmonised and not sufficiently accessible*

There is an increasing amount of data on building energy use and building occupants' energy consumption patterns. Collecting this data and making it available in a transparent way would be useful both for policymaking and to support the creation of innovative energy services and business models, but also to allow for aggregation of renovation projects identifying and targeting priority districts.

***Lesson learned 15:** Creating a framework that systematises data collection and gathering remains a key challenge*

In order to stimulate renovation activities, a framework to systematise data collection by allowing the integration of data from different sources (for example smart meters or EPC repositories) should be created and the automation of the process with minimal, or no, manual intervention should be supported. In addition, digitalisation of data collection should also ensure compliance with data protection regulation and broadly ensure digital security.

Countries have comparatively many policies in place to improve digitalised data collection on the building stock. While there are some attempts to provide digitised data via building logbooks and digital energy performance certificates (and databases), the country research reveals that a systematised, reliable, comprehensive and accessible database is in most cases still missing. This is an opportunity for European policymaking to fill the gap, developing common standards and guidelines or even setting up minimum

requirements to ensure comparability of data across Europe. Blockchain technology enables digital data collection complying with strong data protection requirements. While the research identified several use cases, their practical application remains in niche markets.

Lesson learned 16: *Flexible energy consumption patterns to support the global energy system benefit from a clear definition and an administrative framework*

This area is extensively covered across European countries, although in most cases, there is still ample room for additional policy instruments. Some interesting examples include grants for home automation with remote control of heating, hot water production and air conditioning systems of housing units. Legal provisions help to improve the flexibility and management of the electricity system by supporting new services with independent aggregators of electricity demand. This is important when planning new electricity generation and heating systems in renovated buildings. Another example is the regulation of self-consumption of electrical energy with clear administrative, technical and economic conditions for self-consumption (e.g. what is the definition of a nearby facility qualifying as local consumption?), which allows local consumption to be extended and made more flexible.

Lesson learned 17: *First steps in unleashing the flexibility potential of energy use via digitalised energy-consuming appliances and services are being undertaken in practice*

With the growing penetration of intermittent sources in the power production mix, flexibility is more and more needed on the consumption side. While mature business models already exist for large-scale flexibility harvesting (e.g. industry), the key challenge is to aggregate and harvest small-scale flexibility, e.g. at the residential level. Digitisation is key in this process, which should help to keep the cost of the energy transition under control.

Local consumption of decentralised and variable energy sources is supported by several legislative instruments. Some Member States have put in place legal instruments supporting self-consumption of renewables and distributed generation including financing, third-party energy service models, boosting self-consumption in vulnerable sectors, or promoting the dissemination of distributed production and self-consumption of energy and energy communities. Laws specify protection profiles and technical guidelines for smart measuring systems to ensure data protection, data security and interoperability. They also contain detailed regulations on who may access what data and when.

Lesson learned 18: *The optimisation of energy uses is taking off but are far from being mainstreamed*

Optimising energy use through digitalisation helps to reap the full benefits of deep renovations. Self-regulating devices limit unnecessary energy uses and help to address technical failures that could lead to additional energy consumption. They may also provide more accurate feedback to the consumer and thus stimulate behavioural change.

Most countries have provisions in place to address this challenge, e.g. regulations allowing for electricity bills based on real-time data as a precondition to feed-back information on energy consumption, enabling consumers to modify their behaviour as well as improving energy management. Grants exist to support testing of various technologies with different user groups and bring them to market maturity.

2.4. District approaches

Building renovations can be planned and organised by adopting a comprehensive approach that aims to renovate not only single buildings but rather a district or neighbourhood all at the same time. Renovations at the district level can lead to potentially significant cost savings through an economy of scale and smart logistics. They can also be more attractive to investors thanks to project aggregation and distributed risk portfolios. Moreover, this approach fosters synergies between energy efficiency and other transformation in the district, including the development of local renewable energy sources and urban development strategies. District approaches have the potential to lead to optimal solutions at the macro level, combining energy efficiency with multiple benefits and ensuring consistent sustainable development of cities and territories.

The following key challenges have been identified:

- Developing integrated approaches maximising the synergies between energy efficiency and renewable energy at the district level
- Streamlining and aggregating renovation solutions and processes at the neighbourhood level
- Developing comprehensive (sub)urban strategies combining energy and carbon efficiency of the building stock with sustainable solutions for growth and improvement of citizens' wellbeing

Renovation at the district level can lead to potentially significant cost reductions through economies of scale, the industrialisation of solutions and smart logistics. Moreover, it fosters synergies between energy efficiency and other needed transformations in the district, including joint consideration with the development of local renewable energy sources or urban development strategies.

Lesson learned 19: *Territorial approaches to decarbonisation are typically not sufficiently integrating the renovation of building envelopes and thus fail to maximise the synergies between energy efficiency and renewable energy*

Typical measures to maximise the synergies between energy efficiency and renewable energy are the deployment and decarbonisation of heating/cooling districts, local mapping of the renewable heat potential and supporting energy communities, such as micro-grid initiatives aiming to balance local production and consumption of energy. Although connections with building renovation are not yet explicit in these provisions, they are useful enabling initiatives to structure and embed integrated energy efficiency and renewable approaches to the renovation of buildings.

Lesson learned 20: *Streamlining and aggregating renovation solutions and processes are promising but still niche solutions mainly implemented on a project basis and typically not yet backed by specifically tailored policy instruments*

Most provisions related to the streamlining and aggregation of renovations explicitly foster building renovation at the district level and provide learnings from pilot projects. Despite the generally local character of district approaches, some provisions are structured at the national or regional level, including financial support and training targeted at prefabricated renovation solutions. In addition, public tenders can be used by requiring a minimum project size, standardisation and digitalisation of permitting processes. Finally, adapting legal framework conditions to allow for integrated rents including electricity and heating is in some jurisdictions a precondition for these solutions to become viable.

Lesson learned 21: *The benefits of comprehensive (sub)urban strategies combining energy and carbon efficiency of the building stock with sustainable solutions for growth and improvement of citizens' wellbeing are recognised but far from being fully reaped*

Some provisions structure energy efficiency and renovation plans at higher scales than the individual building. Examples include a web platform supporting the assessment of local renovation needs to promote urban renovation; regeneration and renewal municipal strategies; requirements for municipalities to appoint an energy manager; and combating urban sprawl by reusing "well-located" buildings. Private initiatives also exist, with companies investing in the refurbishment and re-design of districts where they have production sites.

Several countries have infill strategies and rehabilitation of buildings in place, support sustainable urban energy efficiency plans and are carrying out large-scale sustainable urban planning projects (new built) encompassing energy efficiency, renewable energy and health benefits.

Lesson learned 22: *A clear definition of the "district approach" would help unlock its potential*

While there is a common understanding that renovation at the district level would be largely beneficial in many ways, there is no clear and common definition of what a neighbourhood or district approach is.

This is partly because district approaches to efficiently unlock the renovation of the building stock are rather new in political agendas of all kinds. Only a few specific policies consider building renovation at the district level. The pioneering countries in this regard are usually at an experimentation stage and most initiatives are recent (less than five years, and rarely a continuation of previous initiatives/programmes). The level of implementation is typically local. Since it is a rather new approach, most measures have not reached the national level yet, i.e. national legislation or major plans and programmes (national energy and climate plan, long-term renovation strategy (LTRS), etc.). A clear definition of a neighbourhood or district approach would help to facilitate its integration in national legislation.

Besides national, regional and local initiatives, a series of international projects bring valuable insights on the required components to enable and foster district approaches to energy renovation of existing buildings. A selection of success factors from these projects is presented below.

Lesson learned 23: *Mutual trust, clear communication and stakeholder involvement from the very start are key to trigger, develop and efficiently implement district-level renovation projects*

Awareness-raising and capacity building of local administrations are indispensable for the emergence of district-scale renovation projects, given the fact that the main challenge lies in the dissemination and replication of the results. Programme initiators should understand platform-based approaches and methods to empower people. Specialised facilitators can ease the renovation process on the entire customer journey, and several existing provisions recognise the importance of this role. Monitoring committees composed of local stakeholders should follow all initiatives in a district to ensure their consistency with different objectives.

Finally, there is a need for new operating methods to tackle specific challenges of renovating groups of buildings (different starting situations and renovation cycles, different drivers and needs from the diversity of stakeholders, etc.) and supporting tools adapted to coherent district approaches. These methods and tools should ensure the success of projects independent of context-specific aspects inherent in a local approach.

Lesson learned 24: *EU support is important to demonstrate the benefits of district-level approaches*

Financial support can trigger voluntary actions that demonstrate the benefits of district-level approaches and stimulate innovation in business models. This is a precondition to creating followers at the local level throughout Europe. Technical support for local administrations and facilitators is also necessary via a combination of central (EU) and decentralised groups of technical experts. There are already a number of projects not only technically demonstrating how smart and positive energy districts could be implemented but focusing on the impacts and learnings of stakeholder groups and citizens.[24] Finally, the implementation of the Renovation Wave will lead to the implementation of 100 lighthouse projects within the Affordable Housing Initiative.

2.5. Engaging transformation and phasing out inefficient buildings

Engaging transformation and phasing out inefficient buildings is at the core of achieving a decarbonised building stock in the EU. Across the EU, 40% of energy consumption and 36% of energy-related CO_2 are related to buildings. Renovating the least efficient buildings in the EU can contribute to bringing down these figures significantly. To ensure the building stock is fully decarbonised, it is important to develop processes that fully engage end-users and consider occupants' needs. Going beyond providing just technical solutions and engaging consumers in driving change is the only way to create transformative change. This includes supporting consumers with tailored advice for renovations through one-stop-shops or building renovations passports.

In addition, a dedicated framework is necessary to improve the worst-performing buildings, which are often left unrenovated because of market barriers, regulatory failures and other hurdles. Setting mandatory minimum performance standards at a transaction point, such as sale or rental, can have a significant impact on increasing the rate of building renovation, as owners and landlords are compelled to invest in upgrading their properties, shifting poorly performing buildings towards better performance. Mandatory minimum performance requirements are also one of the most effective means for tackling split incentives and related barriers to energy efficiency investments in multi-apartment buildings. Any building policy needs to be well-tailored to specific building segments/building types. For example, heritage buildings cannot easily fulfil all deep renovation requirements. To reflect their heritage value, they are often exempt under current building policies.

The following key challenges have been identified:

- Creating an enabling framework for deep renovations that are not cost-effective
- Triggering acceptance and behavioural change of building owners and occupants about deep renovations
- Accelerating the market penetration of innovative solutions for deep renovations
- Achieving deep renovations in a heterogenous building stock with mixed ownership.

To establish a market for deep renovation to decarbonise the building stock and enable the Renovation Wave, certain challenges need to be overcome. First, an enabling framework for deep renovations that are currently not cost-effective from a purely financial perspective needs to be in place. This may include the incorporation of quantified multiple benefits in the cost-benefit calculations, or grants dedicated to cover

[24] At the EU level, several Horizon 2020 projects are being implemented, e.g. the EU Smart Cities Information System (Available: Website), the Sustainable Plus Energy Neighborhoods project (Available: Website), but also by the Urban Europe Joint Programming Initiative (JPI) (Available: Website), or within the Strategic Energy Technologies Plan.

the margin that is not cost-effective yet. The cost-effectiveness principle should be reconsidered to ensure it does not hamper the required investment in deep renovations.

Secondly, behavioural change and acceptance of deep renovation among building owners and occupants should be fostered by a diverse set of information instruments, e.g. building renovation passports or digital building logbooks. Thirdly, the market penetration of innovative solutions for deep renovations should be accelerated by e.g. dedicated support programmes, e.g. for net-zero renovation projects or for renovation making use of prefabricated facades. Also, the alleviation of legal barriers (such as allowing an increase of rent following a renovation that equals the tenant's energy cost savings) is crucial for innovations to enter mass markets. Finally, these deep renovations need to be achieved in a heterogenous building stock with mixed ownership by e.g. obliging renovation, sharing financing and compensating low-income and vulnerable households.

The challenges have existed already for decades. Most of the legislative and non-legislative policy instruments considered in this study address these challenges at least in part. However, the policy mix is not sufficiently incentivising measures that are not yet cost-effective or accelerating the renovation rate to the necessary level in order to reach the EU's long-term target of a decarbonised and highly efficient building stock.

Lesson learned 25: *Despite numerous policies fostering deep renovations, there is a lack of sufficiently effective, coherent, and well-targeted enabling frameworks for deep renovations that are not yet cost-effective*

While mandatory requirements rarely go beyond those introduced by EU legislation, all countries and regions in the scope of the study have financial support in place to encourage deep renovation (see also the factsheet on financing renovation). Some grant schemes are performance-oriented and provide sometimes sufficient financing for (close to) climate-proof renovation (e.g. the German KfW grant and loan schemes provide higher incentives the deeper the renovation is compared to reference buildings; the Dutch "renovation accelerator" programme provides subsidies according to the primary energy consumption per m²).[25]

While all countries have information measures in place to highlight the benefits of deep renovation, there is little well-targeted information available about wider benefits such as health and wellbeing, and the long-term necessity of measures that are not yet cost-effective for the owner.

Deep renovation of heritage buildings while preserving their cultural value is a challenge that is acknowledged in a variety of policy instruments. This includes the definition of technical adaptation of the renovation requirements and grants dedicated to the renovation of heritage buildings.

An effective, coherent and well-targeted framework would include binding long-term targets and pricing in avoided CO_2-prices as well as taking into account wider benefits of deep renovations.

[25] Other popular schemes, such as the Silesian Catching-up 2 Regions programme with a focus on clean air, lead to partial decarbonisation measures such as the replacement of boilers but not necessarily to deep renovation. The planned MMR scheme in Brussels aims to incentivise only those measures that are already cost-effective within its four-year renovation plan.

Lesson learned 26: *One-stop-shops and comprehensive building renovation roadmaps may trigger acceptance and behavioural change among building owners and occupants towards deep renovations*

Initiatives to change the behaviour of building owners, occupants, investors and other actors in view of facilitating their renovation projects from conception through implementation and monitoring are becoming more common across the EU. One-stop-shops, energy performance certificates and building renovation roadmaps are important tools to inform homeowners about energy consumption to raise awareness and trigger behavioural change. There are also various public information and awareness raising campaigns to promote behavioural change, taking many shapes and forms. In addition, training, networking and exchange platforms are widely established to provide information and incentives to change behaviour.

Lesson learned 27: *The impact of measures to accelerate the market penetration of innovative solutions for deep renovations is still rather low*

Compared to the other challenges, comparatively few policy initiatives have been found throughout Europe to incentivise innovations and acceleration of their market share. One explanation is the comparative novelty of the programmes. However, all actors along the construction value chain are trained to implement well-known concepts that are still economically attractive, so the perceived need to invest in innovation, skills to deploy innovative solutions, and steer business models towards deep renovation is still rather low.

Business models to renovate buildings to a net-zero energy standard making use of prefabrication and automation, support programmes for renovation with prefabricated facades, support for project aggregation and one-stop-shops are policies and measures set up specifically to accelerate the renovation market. Since most of them form only part of niche markets, their impact on the mass market has yet to be proven.

Lesson learned 28: *Mandatory minimum requirements are among the most promising policy instruments to achieve deep renovations addressing the split-incentive dilemma*

Diverse policy instruments and measures aim at improving the performance of heterogeneous building stock with mixed ownership. They range from renovation obligations and requirements, to strengthening tenants' right to demand renovation and landlords' opportunity to transfer a share of renovation costs to the tenant, to energy service company (ESCO) models and funds that support ESCO activity, on-tax financing schemes, information campaigns and other specific services for co-owned buildings.

Mandatory minimum requirements for existing buildings (going beyond EPBD requirements) are among the most promising policy instruments to overcome the split-incentive dilemma. They oblige the building owner to reach a certain level of energy performance in order to ensure the building is e.g. marketable or complies with a certain energy performance level at a specific point in time.

Almost all countries have implemented forms of mandatory instruments to phase out inefficient buildings, e.g. the obligation to upgrade the energy performance of a building when major renovations take place. Most of these instruments are transposing the requirements of Article 4 (and Article 7) of the EPBD, but few go beyond these requirements. A few countries have implemented mandatory minimum energy performance standards (MEPS) for existing buildings to systematically phase out the most inefficient buildings.[26] These are considered the most effective policy instruments to achieve energy savings and GHG emissions reduction. Even if the existing cases are

[26] The assessment of existing MEPS showed that relieving energy poverty has also been a strong motivation among policymakers to introduce these obligations, in addition to reducing the climate impact of the sector.

new and might have to calibrate the policy design to reach the desired impact,[27] they are very valuable frontrunner cases helping to understand good practice design elements.

Another form of regulation found in the Member States is the phase out of fossil-fuel heating. This is a first step to limit GHG emissions, with most practical examples including a ban on oil-fired boilers. Strategies and long-term planning including binding long-term targets are an important precondition for designing effective mandatory schemes to phase out inefficient buildings and preventing technological lock-ins.

***Lesson learned 29**: A comprehensive mix of policy instruments exists to engage transformation and phase out inefficient buildings, but these are not yet effective enough to reach long-term climate targets for the European building stock*

Countries have a variety of policy instruments in place. However, the ambition level as well as the interplay should be improved.

MEPS, funding for deep renovation, progressive EPCs and building renovation passports to better inform homeowners demonstrate ways in which deep renovation can become mainstream. Initiatives to aggregate renovation projects and integrated service providers are also promising examples that could be replicated in other jurisdictions. While there is no silver bullet, there is a growing diversity of better tailored and integrative policy approaches that can be used to trigger further policy development.

- Non-mandatory instruments to phase out inefficient buildings often take the shape of financial support linked to energy efficiency in specific building renovation programmes.
- While those programmes are helping to renovate inefficient buildings, they are neither ensuring a future-proof level of renovation, nor a systematic phase-out of inefficient buildings from the market.
- Informative measures represent an important share of measures in many countries. Raising awareness and sharing knowledge is relatively simple but can be effective to trigger acceptance among building owners, inhabitants and construction professionals as part of a wider policy mix including financial support and mandatory instruments.
- Market-based instruments, in particular CO_2 prices, are considered important complements to widely used financing schemes. However, to effectively reduce carbon emissions in the building sector, the CO_2 price has to be considerably higher than in most existing cases, which poses social and political acceptance challenges.

Some successful subsidy schemes have helped to generate significant energy and GHG emissions savings. While they are quite effective in achieving deeper renovations, they mostly fail to accelerate the renovation activity to the necessary magnitude. Instruments for project aggregation and one-stop-shops are promising measures to accelerate deep renovation of buildings. New accelerator programmes for industrial renovation are combining the insights of innovation theory and existing good practice subsidy programmes. They seem promising; however, the support of production capacity (of e.g. prefabrication of facades on an industrial scale) is still missing in existing programmes and could be the missing link to fully reach the potential impact.

The combination of well-tailored advice for the long-term renovation of individual buildings (in particular, building renovation roadmaps) with financial support and mandatory minimum requirements to phase out inefficient buildings is a promising way

[27] The analysis of existing MEPS shows that parameters such as the compliance system and mechanism, exemptions and simplicity of standards all influence the outcome.

forward. Together, they address all challenges within the area and make sure that long-term targets are reached.

2.6. Financing renovation

Availability of financing and appropriate financing tools are essential to increase the rate and depth of building renovations. Public finance alone cannot support this effort and must be used to leverage additional private investment. Innovative financing schemes and business models are emerging to maximise the effectiveness of funds, as well as to target specific market failures for renovations or more vulnerable groups of citizens.

The following key challenges have been identified:

- Unlocking financing for renovations for the end-users
- Financing building renovations in the presence of market failures
- Mobilising sustainable investment and de-risking energy efficiency investment.

Despite a number of policies and financial instruments implemented in the last decades to address these challenges, investments in buildings remain at suboptimal levels. There is clearly no "silver bullet" to accelerate investments in renovations.[28] Public finance alone cannot materialise the Renovation Wave and should be used to leverage the necessary additional private investment.

The country research shows that the best solution is stable long-term financing, combining public support (grants, guarantees for banks to enable low interest rates, etc.) and innovative financing mechanisms designed to overcome certain renovation barriers (split incentives, lack of upfront capital, etc.), together with wider policy support to make sure the end-users are aware of the possibilities and use them for the best renovation purposes (one-stop-shops, awareness raising activities, tailored renovation advice, etc.).

Lesson learned 30: *There is a wide spectrum of instruments in place to unlock financing renovation for end-users*

To increase renovation rates, there is a clear need to create mechanisms and support programmes which have the financing capacity to stimulate investments, including targeting buildings occupied by the most vulnerable consumers. Those mechanisms come from national, regional and local governments, financial institutions and service providers.

Because the spectrum of policies that can serve to "fix" this key challenge is so vast, the approaches taken by countries make use of the whole bandwidth of financing instruments including grants and loans for specific target groups (involving vulnerable households, elderly), social tariffs, tax breaks and energy saving obligations. Ensuring consistency and complementarity of financing instruments as well as providing orientation about the existing policies remains a challenge in most countries.

Lesson learned 31: *Innovative financing instruments are promising but not yet mainstream*

Innovative financial instruments, such as on-bill schemes and energy performance contracting, are key to increase investments in renovations. The main objective of these

[28] Bertoldi, P. et al. (2020) How to finance energy renovation of residential buildings: Review of current and emerging financing instruments in the EU. *Wires Energy and Environment*.

mechanisms is to move from grant mechanisms towards instruments that can leverage private sector resources.[29]

On-bill schemes exist in several states, regions and local authorities, especially in North America and emerging economies. Programmes vary across several dimensions including the level of organisation (state-wide vs. local programmes), financing structures, and eligible measures. In Europe, experience is limited to the Green Deal in the UK and the Sunshine scheme in Latvia. The analysis shows that while on-bill schemes can successfully overcome important barriers such as upfront cost and split incentives, there are still issues that need to be addressed in order to facilitate their replication in Europe. These include empowering utilities as creditor organisations and fostering their relations with financial institutions, the need to modify billing systems, countering risks of no payment, handling the transfer of property and the change of energy supplier within on-bill repayments, and diversifying sources of capital.

On-tax programmes also exist in several states, regions and local authorities and are being piloted in Europe. They too vary across dimensions including the level of organisation, financing structures, and eligible measures. They reduce first-cost barriers by linking repayment of energy efficiency investments to taxes, thereby allowing customers to pay back part or all of the costs of these investments over time. The funds can originate from utilities, local authorities, the state or third parties, e.g. commercial banks.

Finally, guarantees can provide a valuable solution in cases where financial intermediaries (lenders) are reluctant to fund energy efficiency projects due to high perceived risks. There are different types of guarantee mechanisms, such as loan guarantees and risk-sharing arrangements. By providing financial guarantees to enhance project creditworthiness, guaranteed loans can boost energy efficiency while at the same time reducing tax-deductible interest payments, creating more taxable income for governments.

Lesson learned 32: *Mobilising and de-risking energy efficiency investments*

Lack of evidence on the performance of energy efficiency investments in buildings makes financial risk harder to assess and mobilisation of both public and private investments more difficult. This problem is amplified by a lack of knowledge on the side of the financial sector, along with limited interest due to the small scale of most energy efficiency projects in the building sector. The Smart Buildings Initiative stresses the importance of the need to de-risk energy efficiency investments in buildings by providing investors and private financiers with a better understanding of the risks and benefits of energy efficiency.

In general, de-risking of energy efficiency investments is not sufficiently addressed in the analysed countries. Among the schemes in place are energy efficiency mortgages,[30] crowdfunding[31] and guaranteed energy savings, as well as some targeted information campaigns about the benefits of building renovation.

Lesson learned 33: *Most countries aim to address market failures with financing instruments for renovations*

The approaches taken by countries to diminish the extent of market failures are very diverse but are largely focused on private and public financing (whether via loans,

[29] Ibid.
[30] One example is Triodos Bank, which has introduced sustainability aspects in its home mortgage underwriting process (Available: Website).
[31] The North-West Croatia Regional Energy Agency (Available: Website) established a crowdfunding platform, with the intention to enable investments for energy renovations, which were not attractive to local banks.

grants, tax rebates or on-bill financing) and the promotion of energy services via the support of networking and experience exchanges. Even if most countries are addressing this challenge, additional activity needs to be taken, both in terms of dissemination of existing instruments and in terms of developing additional approaches to address lack of access to information and price in externalities and additional benefits of energy renovation including health and wellbeing.

Lesson learned 34: *Energy efficiency obligations can drive the renovation of buildings*

Energy efficiency obligations (EEOs) are obligations to deliver energy savings placed on energy companies. Once implemented, energy efficiency obligations have the advantage of boosting the market for energy efficiency investments by stimulating the development of new business models such as ESCOs and provide an additional income stream for renovation programmes. In addition, if designed properly including eligible measures, they give a fairly good estimation of the actual savings achieved through the programme.

Lesson learned 35: *Public financing needs to be leveraged by private investments*

Government programmes can partly or fully finance energy efficiency retrofit transactions, and offer subsidised interest rates and placement fees to bank or utility distribution networks for sale and transaction processing services. Low interest rates are a common feature of most national loan schemes in the EU targeting energy efficiency investments.

Private debt financial products designed specifically for energy renovations in buildings are currently not fully developed, as financial institutions are often unfamiliar with these investments and thus perceive energy efficiency loans as high-risk investments. High transaction costs for relatively small projects and failure to offer financing for terms long enough to support deeper measures are additional factors hindering market uptake.

Lesson learned 36*: Well-targeted grants can enable deeper renovations*

Grants are available across most analysed countries and occasionally cover a major share of the renovation costs. Their impact can be considered in terms of deeper renovations. They directly fill an immediate financial gap and thus enable a temporary shift in the market. However, they typically rely on limited resources and can, therefore, neither offer a sustainable solution nor support mass-market uptake programmes. In addition, most grants schemes have not been able to increase the renovation rate but rather helped to finance deeper renovations within the natural investment cycles.[32]

Instead of targeting a specific typology or neighbourhoods (e.g. with high levels of energy poverty), projects are often chosen based on the readiness of the recipient (municipalities, banks, etc.) and the simplicity of the project. If the grant scheme does not require minimum energy performance levels, it risk creating a lock-in effect for future renovations.

Lesson learned 37: Fiscal measures should be utilised to support the long-term objective

[32] An example is the KfW energy renovation support schemes. While the programmes have increasingly financed renovation activity in Germany since their introduction and due to their performance orientation led to deeper renovation, the overall renovation rate in Germany has not increased in the past decade. Even though a considerable number of deep renovations have been financed with the support schemes, the most popular elements of the KfW schemes are single measures compared to whole house renovation (IWU & Fraunhofer IFAM (2017) Monitoring der KfW-Programme „Energieeffizient Sanieren" und „Energieeffizient Bauen" 2017 (Available: Online), see also IWU (2016) Einflussfaktoren auf die Sanierung im deutschen Wohngebäudebestand. Eine Untersuchung im Auftrag der KfW Bankengruppe (Available: Online).

Fiscal measures, such as reduced/incremental property taxation, property purchase taxation, or reduced VAT on renovation components or labour, can be effective in trigger renovations. Tax rebates on personal and corporate income taxes could also be used to incentivise renovations, so the taxpayer sees an instant benefit without having to wait for the grant to be awarded.

Fiscal measures could be used through a bonus-malus system, where building owners with a building that is "future proof" (e.g. based on the EPC rating or building renovation passport) received a tax credit, while buildings trailing the standard will have to pay a fine[33]. One example would be to use the property tax, which then is lowered for future-proof homes and increased for inefficient homes.

2.7. Health and wellbeing

People spend about 90% of their time indoors, so the indoor environment has a significant effect on their health and wellbeing. Many scientific studies show indoor environmental quality (IEQ) plays a crucial role in ensuring our quality of life and general health and wellbeing. The major determinants of IEQ are indoor air quality, and thermal, acoustic and lighting comfort. As well as improving IEQ, energy efficiency renovation also improves outdoor air quality by reducing the use of fossil fuels. Reducing energy consumption through building renovations also reduces energy poverty. Finally, energy efficiency renovations coupled with the elimination of accessibility barriers are also associated with increased wellbeing.

The following key challenges have been identified:

- Integrating health, wellbeing and comfort aspects in legislation and policy instruments associated with renovations
- Enforcing existing provisions in support of indoor environmental quality
- Quantifying health and wellbeing benefits from building renovations and integrating these in the cost-optimal methodology to boost the renovation rate

Inefficient buildings and inadequate IEQ are related and often interdependent, and ought to be addressed holistically. Using public funds for deep renovations to reduce the energy need is an effective way to alleviate energy poverty.

Lesson learned 38: *Many policy instruments, both legislative and non-legislative, integrate health, wellbeing and comfort aspects associated with renovations*

National policies regulating energy efficiency of buildings often mention improved living conditions covering thermal comfort and better air quality as drivers for renovation. Many of the analysed countries have some form of IEQ provisions implemented in their building renovation policies, often as standards, guidance or voluntary IEQ requirements. Countries such as Sweden, Denmark, France, Italy and Ireland apply legislative (mandatory) IEQ requirements (e.g. ventilation and thermal criteria). Ventilation requirements are implemented in building codes in most countries. Dedicated policies regarding noise protection are less often found. The removal of harmful substances, on the other hand, is contributing to a better indoor climate and is taken up by different provisions such as bonuses and grant schemes.

Several research projects are developing new technologies or strategies to improve and monitor the indoor climate. Also, national EPC schemes and awareness-raising

[33] See Pehnt, M. (2015) Integrating individual renovation plans and long-term perspectives into building policy instruments: an analysis of mechanisms and approaches. (Available: Online).

campaigns integrate health, wellbeing and comfort aspects. Energy poverty provisions are implemented in almost half of the analysed countries.

Accessibility provisions for people with restricted mobility are implemented in most of the analysed countries in the form of legislative provisions, standards, guidelines and grants to adapt the building to users' needs. However, they are not systematically used to trigger deep renovation or vice versa.

Despite the existing good practice policies and initiatives, to date, regulatory and legislative measures have failed to fully integrate health and wellbeing aspects in national building legislation.

Lesson learned 39: *Properly designed EPC schemes and voluntary certification schemes could help to enforce and mainstream existing IEQ provisions*

Compared to the mere existence of provisions, the enforcement of IEQ is less advanced. This can partly be explained by the lack of harmonised calculation methodologies and mandatory IEQ requirements across Member States.

Building certification schemes as well as EPCs covering IEQ aspects could spur enforcement when their implementation is mandatory. Some existing EPC schemes incorporate requirements for minimum fresh air rates and protection thresholds for concentrations of indoor air pollutants, offering aspects to replicate. EPCs have the potential to become effective instruments by not only tracking the energy performance of a building but also characterising its overall IEQ through evidence-based information. An important driver of healthy buildings is sustainable building certification systems such as DGNB, LEED, BREEAM, Home Performance Index and WELL which support the provision of health and wellbeing at different levels, favouring the indoor environment, ecology, socio-cultural aspects, active and healthy lifestyles, and safety. Practical examples show also that it is feasible to mandate certifications, e.g. LEED certification, for certain commercial and municipal new buildings. Level(s), the recent EU-wide framework for sustainable buildings, includes health and comfort among its target areas and uses indicators for indoor air quality, and thermal, acoustic and lighting comfort.

Lesson learned 40: *Systematic quantification of health and wellbeing benefits and their integration in the cost-optimal methodology to boost the renovation rate are still lacking.*

In general, there is a lack of cases quantifying the health and wellbeing benefits from building renovations across the analysed countries. The existing provisions only touch upon the topic but are not particularly helpful in addressing this challenge.

Although the Joint Research Centre (JRC) has published a report on 'Promoting healthy and energy-efficient buildings in the European Union' showing various studies that have quantified the benefits in terms of improved quality of life, a common systematic and holistic quantification approach for health and wellbeing benefits of energy renovation among EU countries is lacking. Some research projects were identified but a large-scale integration of quantified IEQ benefits in cost-optimal calculations is missing.

Lesson learned 41: *Close monitoring could increase data availability as a precondition for sound policy integration for health and wellbeing aspects*

In order to better assess the effectiveness and impact of existing provisions, ongoing close monitoring and evaluation of the implementation progress of policies are essential to increase the data availability (for IEQ this is still very limited). In particular, private programmes and initiatives, e.g. building standards/certifications, are often not monitored or the data is not publicly available.

2.8. Deducing lessons learned with cross-sectoral relevance

There are considerable challenges towards achieving a decarbonised European building stock compliant with long-term objectives in adjacent areas such as ensuring clean mobility, a sustainable built environment and climate adaptation, as well as the health and wellbeing of all citizens. To ensure that policies from different areas mutually reinforce rather than impede each other, a high level of policy integration across areas is required.

The study looked at areas that already have an integrative character and may help to facilitate synergies, namely digital technology for energy renovation, financing renovation and district approaches. Insights from these areas are mirrored with lessons from other areas. A set of comprehensive lessons learned is presented below.

***Lesson learned 42**: Objectives can only be achieved with a sound policy mix*

The identified set of policies constitutes a promising menu to build effective policy mixes for contributing to GHG emission reduction. Regulatory approaches – when combined with effective administration, monitoring and enforcement – form an important baseline to set conducive framework conditions and motivate compliance. Using economic and fiscal incentives to help create markets and reward circular approaches (and/or penalise linear ones) seems equally important in order to foster innovation and support so-called first movers in more sustainable markets. As innovation thrives where peer learning takes place, providing room for networking and dialogue across the building sector (and its value chain stages) appears essential to enshrine progress towards circular and low-carbon buildings and construction on the supply side.

This shows the interrelation of different policy instruments: a sound legal basis is needed to provide objectives (e.g. secondary material quotas or enshrining in legislation the obligation to monitor and consider embodied carbon in buildings by comparing different design choices, including material use, as well as procurement criteria) and create sanctions for non-compliance. This in turn enables establishing a level playing field across market actors in the building sector. At the same time, specific incentive structures can give circular products and services a competitive edge. This is likely to function best (or only) if all key players are involved and engage in dialogue and joint action based on optimal flows of information. Reporting and assessment are important to facilitate learning about the impact of design and material choice. Requiring information for permitting can already create a shift in the market towards more awareness and better performance.

The country review carried out in this study showed that the European regulatory framework relevant to the built environment and more specifically the EPBD had a major impact on policy development in EU Member States. The combination of well-tailored advice for the long-term renovation of individual buildings (in particular, building renovation roadmaps) with financial support and mandatory minimum requirements to phase out inefficient buildings is a promising way forward.

***Lesson learned 44:** Regulation and mandatory minimum requirements are seen as an indispensable part of the policy mix in most strategic areas*

Regulatory requirements are among the most promising policy instruments to effectively address the split-incentive dilemma – one major barrier towards deeper and faster energy renovation. Also, minimum requirements for data collection, e.g. via EPCs, for urban planning or sustainable building design are impactful instruments to set a more ambitious baseline for action at the Member State level.

A range of regulatory instruments and mandatory requirements are already in place but vary in their level of application. They include:

- MEPS for existing buildings (see separate report on Task 4)
- Minimum requirements for data collection, e.g. via EPCs or climate declarations
- Phasing out of fossil fuels for heating in buildings
- Mandatory quotas (e.g. energy saving obligations, minimum quota for the use of secondary materials)
- Minimum requirements for urban planning.

Lesson learned 45: *There is further need for effective trigger points to enact deep renovation*

Trigger points are key moments in the life of a building (e.g. rental, sale, change of use, extension, repair or maintenance work) when carrying out energy renovations would be less disruptive and more economically advantageous than in other moments. Available funds often reach recipients that have a well-developed project in place. While the EPBD already emphasises the importance of trigger points to activate renovation beyond business-as-usual, country research shows that there is still room for strengthening the use of trigger points and to think of new trigger points. One example would be to define trigger points in improving accessibility for people with disabilities[34] to capture opportunities for deep renovation, and vice versa. To enhance the impact of trigger points, financial support could be made conditional to fulfilling regulatory requirements.

Policymakers should consider opportunities that facilitate the success of trigger points from a user's perspective. They should make sure that all relevant information is easily accessible, via independent advisers (including one-stop-shops) and suppliers, and that other existing requirements do not constitute a barrier to renovation (e.g. in multi-apartment buildings, the decision to insulate the roof has to be taken by several homeowners, which may hinder deep renovation by limiting efficiency measures to individual apartments).

Lesson learned 46: *A general lack of data needs to be addressed*

The lack of data is a persisting challenge across all strategic areas. Existing databases, such as building registries and cadastres, EPC databases, material passports and the European Building Stock Observatory, differ in collection methodology, data specification and thus comparability, comprehensiveness and availability. It is therefore difficult for public authorities to utilise the existing data for compliance checking (of subsidies or renovation obligations) or to use in the development of new policies and measures (where better data will allow for a better apprehension of the situation, which in turns enables the development of more tailored policy designs).

Better and more comprehensive data is needed to understand the performance and the overall condition of the EU building stock, which to a large extent is still lacking. This includes data derived from EPCs, data on real-time energy consumption and according to monitoring and display, the share of renewable energy, carbon emissions, the whole-life carbon impact of buildings, additional benefits and the smart-readiness of the building. Data gaps exist across the spectrum but even more for the new focus areas, including whole-life carbon emissions and smart building aspects (e.g. demand response capacity, EV charging).

The private sector is the key enabler in this effort, as it already produces and gathers a large amount of building data. Data is, for example, created and gathered by the construction manufacturers, engineers, architects, construction workers, energy auditors, facility managers, utility companies and by the building owners themselves. Yet the fragmented approaches to data collection at different stages of a renovation

[34] See for example, the European Accessibility Act, which is a directive that aims to improve the functioning of the internal market for accessible products and services, by removing barriers created by divergent rules in the Member States.

journey can only be solved through concerted efforts by the EU and it Member States, making sure the data is shared, interoperable and useful over the whole lifecycle of buildings.

Only concerted efforts at EU and national level can overcome these barriers. Entry points for this include:

- Enhancing data availability and extending data collection on the building stock beyond energy performance
- Mandating the establishment of digital building logbooks
- Supporting pilots testing blockchain technology for building renovation to enhance data protection and allow for project aggregation
- Enhancing and harmonising guidelines for data specification and data collection approaches
- Supporting harmonisation and standardisation of building data, to ensure syncing/matching between different databases and comparability between buildings, cities and countries.
- Encouraging data collection at the local level by a) providing financial support to municipalities for data collection, b) providing technical assistance to municipalities, c) supporting citizen science projects.

Lesson learned 47: *Digital building logbooks can help fill the data gap*

A policy instrument that has gained cross-sectoral attention is the digital building logbook. For each strategic area, it serves slightly different purposes. The most reliable data is gathered by an energy expert on-site, which comes with a considerable cost. On the other hand, on-site visits by experts have also shown to be effective in encouraging the owner to invest in deeper and higher quality renovations.[35] Digital building logbooks can make sure experts have all possible information before vising the building, which will reduce the required time on-site and thus also the related cost. Related to this, energy experts ought to be trained to have a more holistic understanding of the building and its interaction with the district and wider energy systems.

The possible functionalities of a digital building logbook include:

- Acting as a single repository of all relevant building data,
- Increasing the lifecycle perspective for new and existing buildings,
- Informing planning by collecting and mapping data to better identify priority areas/districts for aggregated renovation projects
- Feeding climate vulnerability and risk assessments with data and storing the results of these assessments
- Integrating mobility planning
- Integrating administrative information such as permits and requirements for compliance
- Informing individual building owners about renovation steps contributing to the long-term policy targets of the building sector
- Facilitating circular approaches to renovation such as deconstruction and reuse of existing elements
- Making use of blockchain technology to ease data sharing without compromising on data security
- Including information on IEQ

[35] See e.g. Fabbri, M. et al. (2019) Technical study on the possible introduction of optional building renovation passports. European Commission. (Available: Online).

***Lesson learned 48**: Strengthening energy performance certificates could create multiple benefits*

In implementing the EPBD, EU Member States have established national EPC schemes. Improved and better-aligned EPCs could be beneficial to many strategic areas. They could include information on the carbon performance, provide information on renovation costs and help to better capture trigger points. They could be a dynamic data repository once digitalised, online and accessible, and prove compliance with policies (e.g. with mandatory minimum performance requirements; eligibility for financial support, etc.).

***Lesson learned 49:** Urban planning is a promising way towards policy integration*

Urban planning is the obvious choice for the integration of different strategic areas (buildings, heating/electricity systems, sustainable mobility etc.). Planning takes place at different scales and should be used to prevent urban sprawl, operationalise aggregated renovation projects and integrate infrastructure for sustainable mobility. To unlock the planning potential, the EU should recommend the specification of minimum requirements in existing urban planning, e.g. for mobility plans to the extent possible through existing directives (e.g. SEA Directive[36]), or require Member States to report on how they take certain aspects into account in their national and subnational planning tools.

Planning can make better use of:

- (New) planning principles such as the 15-minute city, the energy efficiency first principle and re-densification,
- Tools to digitally map data
- Systematic consideration of climate adaptation measures, including at district level, through green and blue infrastructure, to also prevent negative effects,
- Design criteria to implement a lifecycle perspective
- A framework to monitor building performance and to collect data at the district level.

***Lesson learned 50:** New approaches need to become better known across sectors*

The country research revealed that while some concepts are well known at the European level and among scientific and academic stakeholders, many policy concepts need further explication and dissemination, both vertically to national and subnational governance levels, and across sector.

Among those are:

- Ways to de-risk investments in energy efficiency
- New ways of financing such on-bill or on-tax financing
- Project aggregation and an overview of renovation services via one-stop-shops
- Defining nature-based solutions and climate adaptation measures
- Defining and delineating the neighbourhood/district approach
- Understanding of lifecycle approaches as well as the potential of circularity principles in achieving carbon reduction
- New mobility concepts such as the 15-minute city
- Benefits of deep renovation for health and wellbeing and the importance of IEQ
- The importance of energy renovation for systemic energy transitions
- The links between renovation rates and waste, material use and embodied emissions

[36] Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (Available: Website).

- The economic impact of delivering a sustainable built environment

A clear definition and better dissemination of the significance of these concepts would prevent unintended consequences from noncomprehensive planning and maximise synergies.

Lesson learned 51: *Financing remains a bottleneck for implementing a decarbonised and sustainable built environment*

Financing has been identified as a bottleneck in many strategic areas examined in this study. Innovative financing instruments need to become more widely deployed, which requires promotion campaigns, collaboration with local banks, and innovation support for SMEs. In addition, new business models are required to facilitate the Renovation Wave, such as aggregation of renovation projects, the use of prefabricated systems for deep renovations, and the use of robotics and automation to optimise the process. Multiple opportunities for the construction value chain will arise, driving marginal improvement as well as larger disruptive innovations. Long-term financial support mechanisms, public and private, are needed to kick off the transformation and to ensure companies make the long-term capital investments (such as in factories to facilitate large-scale production of prefabricated facades or HVAC).[37]

Lesson learned 52: *Available digital technology should be rolled out to enable promising approaches to support the creation of a sustainable built environment*

Digital technology development is advanced e.g. in reaping flexibility gains from the demand side, but it is not fully exploited for the creation of a sustainable built environment. For example, while BIM is ready to be used in constructing new buildings, it is not yet mainstream in most markets and only a few solutions exist for the renovation of existing buildings. New opportunities to utilise digital innovations to decarbonise the existing building stock are still not fully explored, due to path dependency or the remaining profitability of traditional practices. Better data collection and the use of digital solutions (e.g. making use of blockchain technology, digital building logbooks, or at least improved and web-accessible EPC databases) can steer the reorganisation and optimisation of construction and renovation processes. The availability of robust data enables new business models and better-targeted building renovation policies. Subsequently, building renovation could be organised along with priority areas, be compliant with long-term targets and be delivered at a faster pace.

Lesson learned 53: *Transparent communication and stakeholder engagement are important success factors*

Across all strategic areas, transparent communication and stakeholder interaction and engagement help to build mutual trust and are key to enforce promising solutions. This is especially relevant for urban planning but not restricted to this. There are several ways the EU is already promoting participatory approaches and communication. Besides supporting exchange and engagement by requiring participation processes, setting out guidelines or supporting networking, good practice exchange demonstrating the multiple benefits of building renovation could be an important driver.

Lesson learned 54: *Market-based approaches have limited significance in existing policy mixes*

While there are examples of market-based approaches for building renovation and for the wider built environment, such as CO_2 pricing, the extension of the ETS to buildings and road transport, secondary material quotas, aggregate levies and energy saving

[37] See the experiences of the Energiesprong model, which is being developed in the Netherlands, France, Germany and Italy. (Available: Website).

obligation schemes, they currently do not play a major role in decarbonising the building stock. This may be due to the still-moderate targets and price levels found in existing cases (also driven by social acceptance constraints), although some instruments have delivered energy savings and GHG emission reductions. Another plausible reason is that many of the barriers to renovation are non-economic barriers and can thus not be fixed with market-based approaches solely.

3. IDENTIFIED AND SELECTED POLICY ACTIONS

The last section of the study considers the lessons learned from all strategic areas and further channels them into policy actions to be considered at the European level.

The chapter operationalises the main lessons learned from the above analysis, together with insights from the good practice examples (Annex III). The first step was to identify a pre-selection of possible policy actions based on the good practice examples[38] for each strategic area, which were derived from the analysis of policies and measures in 15 Member States, 3 non-EU countries and 5 regions (Appendix). The second step was to discuss the identified and possible policy actions with leading experts in different fields and to develop an impact consideration and SWOT analysis of the identified actions. Based on the analysis, 24 policy actions were selected and divided into 7 cross-sectional clusters.

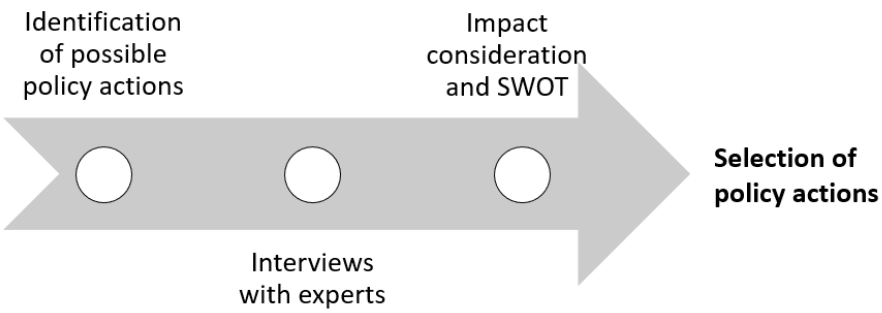

Figure 5: Methodological approach to select policy actions

Interviews

For each of the strategic areas, 1-3 qualitative expert interviews were carried out based on the preselected list of provisional policy actions (see Appendix). The experts were asked to validate the provisional policy actions and supporting good practice examples. Conditions for their implementation were addressed as well. This included (1) policy design elements to increase the impact, (2) the role of enabling measures and (3) suggestions for how the respective policy actions could be supported at the EU level.

16 in-depth interviews were conducted in a semi-structured way following a set of guiding questions. The interviewees were provided with the set of policy actions, as well as some background information including the main lessons learned, and the list of good practice examples per area before the interview took place. The expert input was used to substantiate and test the findings and conclusions of this report.

3.1. Analysis of the selected policy actions

Each policy action is presented in this chapter through a description of the main rationale and the central design characteristics and success factors. A light impact consideration indicating the potential impact and a summary of the strengths, weaknesses, opportunities and threats (i.e. SWOT) are also presented for each selected action, according to:

- Design characteristics
- A light qualitative assessment of its potential impact alongside a pre-selected set of criteria
- A summary of the strengths, weaknesses, opportunities and threats.

[38] The initial list of good practice examples can be found in Appendix 6.1.

Impact consideration

Each policy action contains a short section describing the assessment of the potential impact. The impact consideration is based on the available evaluations of existing policies that underpin that particular policy action, the external experts' evaluation, as well as an internal assessment based on the expertise within the consortium. Existing literature and evaluations of similar policies have also been used to support the impact consideration.

It should be noted that the impact considerations are only light and qualitative and only intend to indicate the potential of different actions. The rating should be viewed in the light of this and rather be seen as a starting point for further in-depth analysis, within the context of another study.

Each policy action has been checked against the following impact categories:

Indicators

- Reduction of primary energy needs
- Reduction of CO_2 emissions
- Increased renovation rate and depth
- Reduction of energy poverty
- Improvement of health and wellbeing
- Increased sustainable infrastructure in the built environment
- Increased smart readiness

Since the policy actions have different areas of origin and vary in their objectives, information is not always available for all impact categories. The categories reflect on a very general level the challenges of the strategic areas. When information was not available, an estimation of the potential was carried out instead in a qualitative way and wherever possible evaluated through the expert interviews.

The rating is simply based on a scale from "minor impact" to "excellent impact". As it has not been possible to quantify the potential impacts, the criteria are also qualitative. "Excellent impact" means that the suggested policy action is expected to be very effective. For "primary energy savings", this means the action is expected to trigger considerable energy savings. "Minor impact" means the action will have some impact but with a marginal total effect. As the scale only has four alternatives, in terms of impact, it does not mean that two policy actions with the rating "excellent" are expected to have the exact same impact, just that both impacts are expected to be considerable.

Table 1: Example of impact consideration rating

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

SWOT analysis

A light SWOT analysis has been carried out for each policy action, based on the good practice sheets (Task 2.3 and Task 3.3), which also contained SWOT analyses. The SWOT analysis is also supported by evidence gathered through the project and the interviews with experts. The strengths, weaknesses, opportunities and threats are discussed in view of their relevance to addressing the challenges per strategic area, including the ability to trigger a fair transition process and the upgrade of the urban context to achieve multiple benefits and cross-area synergies.

3.2. Roadmaps for implementation at the EU, national, regional and local level

The policy roadmaps are formulated around six clusters. Each cluster has been built around a narrative, relevant across different strategic areas. This allows us to come up with additional insights on how relevant actions could be most effectively combined and sequenced to maximise desired impacts and foster synergies between strategic areas (built environment sustainability and adaptation to climate change, clean and sustainable mobility, digital technology, district approaches, engaging transformation and phasing out inefficient buildings, financing renovation, health and wellbeing). It also avoids a silo approach to policymaking and is thus more suited to tackle the current challenges in the building sector.

The selected policy actions are relevant at least for three strategic areas and help to understand and accordingly tackle overlaps and synergies between those areas. Apart from the description of design elements, the impact assessment and the SWOT analysis, a timeline and suggestions for how the option could be supported at the EU level, including an enabling framework, will be elaborated. They will be based on policy actions and not solely focused on one strategic area to foster policy integration and problem-solving.

Upfront of a more detailed presentation of the respective policy action, its relevance for the strategic area is depicted in the following illustrating example (policy action would be relevant for sustainable mobility, engaging transformation and financing renovation):

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing


Cluster 1: Align policies with long-term objectives
Define "decarbonised building stock" and require Member States to introduce local LTRS to build positive energy districts
Mandate Member States to plan for an upgrade of the nearly zero-energy building definitions, to make sure they support the 2050 objective
Develop a detailed strategy for the European building stock and the built environment on adaptation to climate change, identifying priority actions, and mandate all local authorities to formulate strategies and action plans
Revise the cost-optimal definition to incorporate all renovation-related benefits
Cluster 2: Introduce regulatory and market-based instruments for the transformation of the European building stock
Introduce an EU-wide carbon price on road transport and heating fuels that increases progressively over time
Introduce mandatory minimum energy performance standards for existing buildings
Introduce minimum mandatory green public procurement criteria for all new buildings and renovations
Introduce mandatory minimum IEQ standards for all schools and hospitals
Introduce a requirement for inspection of stand-alone ventilation systems in residential buildings
Address climate change adaptation in new and existing buildings
Cluster 3: Enhance the gathering, availability and harmonisation of building data and information
Improve reliability and increase the scope of EPCs to include and display CO_2 performance, history and likely outlook of actual energy use and demand-side flexibility
Mandate Member States to introduce building renovation passports as an advisory tool, providing stepwise advice to achieve a future-proof building
Introduce a requirement on assessing and reporting lifecycle aspects, starting with new and public buildings and then progressively widening the scope
Mandate Member States to make building-related data available and accessible in a digital building logbook
Cluster 4: Facilitate the market penetration of innovative financial mechanisms
Support Member States to set up national decarbonisation funds
Mainstream energy performance contracting and use financial guarantees to enable deep renovations
Establish a regulatory framework to enable utilities to enter the market of on-bill financing schemes and allow for transferable loans attached to the meter
Support regional one-stop-shops to create a smooth renovation journey for private citizens and municipalities
Cluster 5: Accelerate renovation and flexibility in the built environment by utilising digitalisation and automation
Require public and large new buildings to include an interoperable energy management system and continue to remove legal barriers to enable demand-side flexibility in buildings, including BACS, electric vehicle charging stations, demand response and automatisaton
Introduce integration of BIM in urban planning and require it for larger new buildings and public infrastructure projects
Enable public and private entities to aggregate demand for energy renovations, to facilitate higher production rate and industrialised renovation approaches
Cluster 6: Achieve policy integration through information exchange hubs and integrated urban planning
Guide and require municipalities to identify and support energy-poor groups
Require integrated municipal planning
Ensure district-level application of green and blue infrastructure for new and renovated buildings and in public space
Support regional exchange platforms to trigger innovations, collaboration and replication of good practices

3.3. Cluster 1: Align policies with long-term objectives

The first cluster of policy actions comprises framework conditions to ensure that the measures are delivering European objectives. While Article 2a of the EPBD sets the bodywork for how the European building stock needs to become highly efficient and decarbonised by 2050, the operationalisation of this target into practice is still awaited. Member States' long-term renovation strategies (LTRS) are the first strategic tool to operationalise this objective. Both the outcomes of this study and a first LTRS evaluation[39] show that the existing policy mix is not sufficient to keep the Member States on track to decarbonising the building stock by 2050. There is a lack of a concrete definition[40] of a decarbonised building stock, which could guide policymaking at the local level while sending a clear and unambiguous signal to investors and the construction value chain. It is only with a clear definition of what is at stake that Member States can resolve the inconsistency between their long-term targets for their building segments and the long-term target framed at EU level, and elaborate the right policy mix to steer the transformation with the right level of efforts.

To decarbonise the European building stock by 2050, policymakers at all governance levels need to know what a future-proof building will have to look like. Stock-taking and defining the role of certain building stock segments (residential single family and multi-family buildings, public buildings, office buildings, etc.) are needed to design a practically relevant tool. This includes a reflection and evaluation of existing nearly zero-energy building (NZEB) standards in the Member States. Further, the role of renewable heating and cooling to meet the objective needs to be considered strategically.

The national LTRS should be transposed to the local level with urban districts as key infrastructure to guide implementation on the ground. The EU could mandate this as part of the required elements to be developed by the Member States in their LTRS and national energy and climate plans; national frameworks for local long-term joint strategies should be provided to enable holistic and synergetic approaches between decarbonisation and deployment of fossil-fuel-free districts, mobility, digitalisation, sustainability, adaptation, health and financing. The national frameworks should also foresee cross-cutting governance and monitoring frameworks to steer interlinkages when transposing such joint strategies at the local planning level. To be viable strategies, the measures will have to link to individual living conditions and touch upon the entire built environment to capture the multiple benefits associated with decarbonising the EU building stock.

Measures that are now changing the building stock should be future proof. While climate mitigation measures are crucial, adaptation measures are becoming increasingly important. Therefore, a strategy for the European building stock will have to detail also how measures will contribute to adaptation to climate change, create synergies between mitigation and adaptation measures, and minimise possible mutual negative effects both types of measures may have.

The policy actions in this cluster have been derived and designed to complement each other. While action 1.1 is setting out a roadmap to a decarbonised building stock highlighting the importance of districts and the local level, action 1.2 foresees an updated NZEB, which makes sure new buildings are "future proof". Action 1.3 pays special attention to the link between climate mitigation and climate adaptation aiming for a more detailed action plan on adaptation measures in the built environment at all

[39] BPIE (2020) A review of EU Member States' 2020 long-term renovation strategies. (Available: Online).

[40] Examples of uncertainties include questions such as the scope of the carbon emissions (e.g., are embodied emissions included or just operational energy?) and the requirements in terms of energy "autonomy" (does it require buildings to be net-zero energy on an annual, monthly or daily basis? How are on-site and off-site renewable production accounted for?).

governance levels. Finally, action 1.4 proposes a review the cost-optimality calculation to reflect and enable new NZEB level in view of long-term objectives.

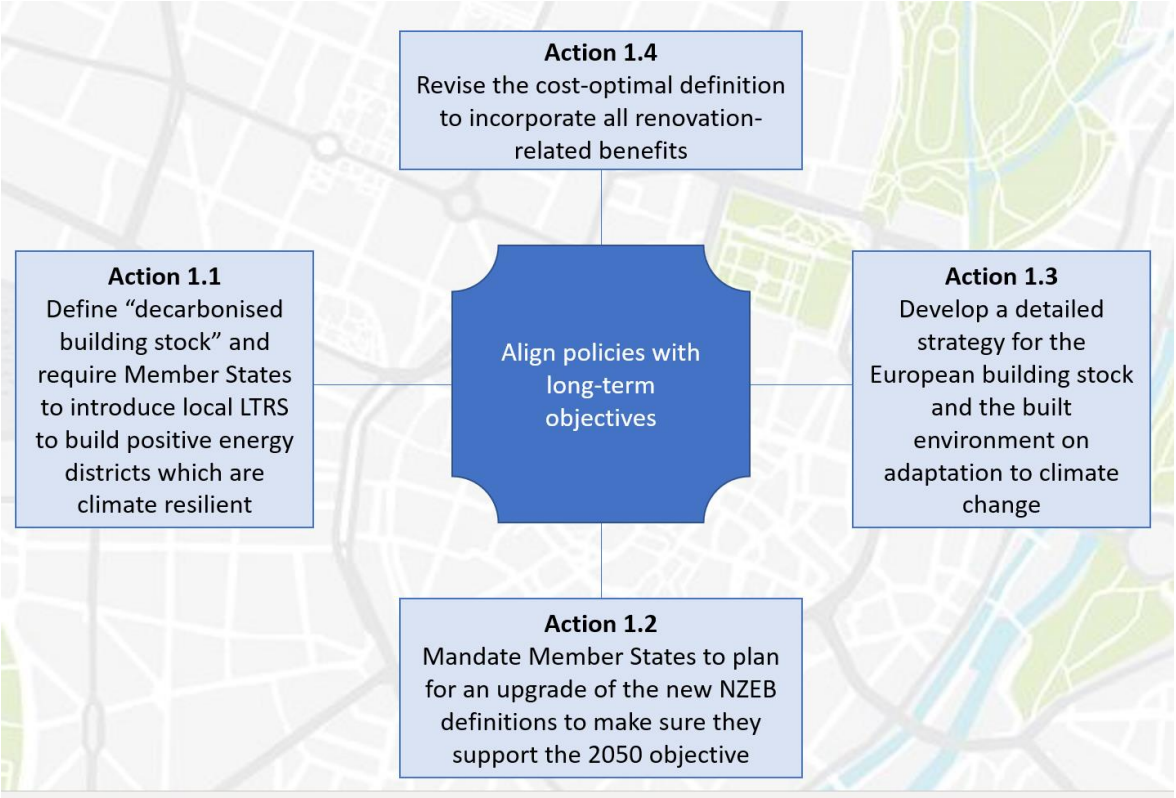

Figure 6: Policy actions in Cluster 1: Align policies with long-term objectives

Policy action 1.1: *Define "decarbonised building stock" and require Member States to introduce local LTRS to build positive energy districts which are climate resilient*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: There is currently no common definition of a "decarbonised building stock".[41] A definition would make clear what is expected from the building stock by 2050, at the European level, Member State level, regional level, district level and at the individual building level. The long-term renovation plans could then be adapted to aim for this common goal.

- The national LTRS already include roadmaps to achieve a decarbonised building stock by 2050, yet with different levels of detail or summarisation of how it will be achieved. Not all Member States reflect on what "decarbonised building stock" will translate to in the average energy performance level of the building stock, and how it can be achieved.[42]
- This study has identified the local level (municipal or sub-municipal/district level) as a key jurisdiction to enable decarbonisation of the built environment. Urban planning can be utilised to tackle several strategic areas (sustainable mobility, district approaches, engaging transformation, adaptation etc.) in a holistic way. This policy action suggests that the national LTRS are transposed to the local level, where the local jurisdiction must outline a similar strategy, taking into account the local building stock, adaptation needs, heating system, sustainable mobility plans etc. The local plans should also include a notion of how they are building, or enabling, positive energy districts, which are needed to support the wider decarbonisation effort.[43]

Why: Article 2a of the EPBD requires the Member States to "Establish a comprehensive strategy aimed at achieving a highly efficient and decarbonised building stock by 2050 and cost-effective transformation of existing buildings into NZEBs". At the same, the local level is a key arena of decarbonisation. The EU's energy and climate governance has primarily been based on top-down policies, which risk missing the bottom-up system that ensures consistency of EU, national and local policy actions and incentivises decarbonisation at the local level. Transposing the national LTRS could bridge this divide while making the implementation of the LTRS more effective. While this is primarily a task for the Member States, the EU can nudge and support this process as well. As noted, a decarbonised built environment will rely on the spread of positive energy buildings and districts, enabling flexibility in the energy system and integrating electric mobility, which is best addressed at the local level. Adaptation efforts can advantageously be integrated at this level too.

[41] The Commission Recommendation (EU) 2019/786 states "A 'decarbonised' building stock is not defined in EU legislation, but it can be considered as one whose carbon emissions have been reduced to zero, by reducing energy needs and ensuring that remaining needs are met to the extent possible from zero-carbon sources. This approach allows for various routes to decarbonisation, taking into account the Member State's national energy mix, preferences, potential and characteristics."

[42] The Flemish LTRS is considered a good examples, and states that "This long-term objective means that by 2050 the average EPC figure for the entire housing stock will be reduced by 75%. On the EPC scales used with energy labels (A to F), this corresponds to label A." This realisation is also used to guide the supporting regulatory and financial actions in the region. (Available: Online).

[43] Positive energy districts are energy-efficient and energy-flexible urban areas or groups of connected buildings which produce net-zero GHG emissions and actively manage an annual local or regional surplus production of renewable energy. They require integration of different systems and infrastructures and interaction between buildings, the users and the regional energy, mobility and ICT systems, while securing the energy supply and a good life for all in line with social, economic and environmental sustainability. Source: JPI Urban Europe (Available: Online).

Structuring the action at the local level will allow for:

1) Proper integration of climate adaptation and urban regeneration efforts,
2) Higher impact on sustainable urban development (e.g. strategies to avoid urban sprawl) and energy system transition processes
3) Steering societal innovation and citizen participation
4) The implicit incentive for project aggregation and upscaling.

How: The EU should define what a "decarbonised building stock" comprises and ask Member States to translate this into their national LTRS. Article 2a of the EPBD should be amended to mandate Member States to include measures on how they are working to increase the uptake of positive energy districts, including links to the Renewable Energy Directive (RED II). The directive should also provide a clear definition of a "positive energy district" and how to ensure they are climate-resilient. Horizon Europe can be used to develop and explore innovative district solutions, enabling cost-optimal solutions. This way, integrative local planning can be ensured.

When: Introduce a requirement in the planned EPBD revision [2021]. Ensure that complementary supply-side measures are taken up in RED II revision [2021].

Existing cases: The EU Smart City Information System provides ample examples of good practices.

- Project Zero in Sonderborg, Denmark, is one inspiring local example, where building renovation, heating system decarbonisation, sustainable mobility and citizen participation are tackled in a comprehensive and forward-looking strategy.

Impact consideration of Policy Action 1.1

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Shifting the focus from buildings to districts, and from energy performance of individual buildings to positive energy performance of districts, results in a new, higher level of impact on sustainable urban development and the energy transition process	Focus on districts could lead to the watering down of existing minimum standards for individual buildings as well as individual incentives and responsibilities Requires new skills/ vision/ planning ability and resources (and legal competences) at the local level	Increase the energy efficiency of districts and facilitate energy transition at the urban scale, integrating holistic approaches Develop societal innovation and citizen participation Implicit incentive for project aggregation and upscaling	Positive energy districts focus on the building aspects and there is a risk of missing important aspects such as transport, public spaces and lighting etc.

Policy action 1.2: *Mandate Member States to plan for an upgrade of the new nearly zero-energy building (NZEB) definitions to make sure they support the 2050 objective*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: By 2050, all buildings will have to be net-zero energy/carbon buildings, which means the operational energy must be net-zero, or even positive, while the embodied carbon emissions are minimised. To support this objective, new constructions ought to be net-zero emissions over their lifecycle as soon as possible. If the buildings we build in the coming decade(s) will also have to be renovated before 2050, the decarbonisation vision might become unobtainable.

The effectual EPBD requires all new buildings to be NZEB from 2021. According to Article 2 of the same directive, "nearly zero-energy building" means a building that has a very high energy performance, as determined per Annex I, and is supplied by energy from renewable sources, including on-site renewable energy production. While the NZEB definitions are a large leap forward, they are not necessarily aligned to create a decarbonised building stock by 2050.

EU policy efforts on energy efficiency in buildings stared in the 1970s and have translated into ambitious building regulations across the union.[44] The progressive building regulations have pushed the market and triggered innovation. The new requirements should be published well before they are enforced, to provide the market with sufficient lead time. Evidence from countries shows that many investors choose to comply with the future requirement long before it comes into force.[45]

Why: Ensure that new constructions are "future proof" while creating a market for highly efficient measures and technologies and renewable energy solutions. This also allows flexibility since not all individual buildings can achieve a highly efficient level (e.g. some heritage buildings). This could be compensated by neighbouring buildings achieving positive energy levels.

How: Introduce obligation on MS to upgrade their NZEB definition in EPBD to make sure it aligns with the 2050 objective

The definition should also underpin strategic documents, including the national long-term renovation strategies and national energy and climate plans. The definition can also be integrated into energy performance certificates (e.g. align with EPC label A) and the building renovation passport.

When: Introduce in planned EPBD revision with five years of lead time.

Existing cases:

- In Slovenia, there is a LIFE project called Care for climate, which is developing criteria for sustainable buildings in Slovenia.
- In Croatia, new constructions must be designed, built and demolished in such a way that material is durable, recyclable and favours secondary usage.

[44] Economidou, M., et al (2020). Review of 50 years of EU energy efficiency policies for buildings. *Energy and Buildings* 225. (Available: Online).

[45] See Danish and Flemish NZEB introduction, where the long lead time and progressive approach guided the markets. The Dutch MEPS introduction for offices also impacted the market several years before coming into effect (see Annex IV).

- Private certification tools, such as BREEAM, LEED, HQE, SBTool, DGNB, all have ratings going beyond the NZEB requirements, in terms of ambition and scope.

Impact consideration of Policy Action 1.2

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Setting out a clear, long-term vision to which strategies, standards and other measures can adapt Definition aligned with 2050 targets	The NZEB experience shows that Member States apply diverse approaches to the definition of national standards	Drive market transformation and create a dynamic development in steering real estate investments and portfolios	Risk of fragmented definitions across the EU, clouding the clear message for the market Differentiation between new and existing building definitions The NZEB transposition/implementation deadline is close to the publication of this study - avoid creating confusion on the market and implementation delays anticipating a new definition

Policy action 1.3: *Develop a detailed strategy for the European building stock and the built environment on adaptation to climate change, identifying priority actions, and mandate all local authorities to formulate strategies and action plans*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: The EU building stock is vulnerable to climate change. The adverse effects of climate change, in terms of more extreme weather (e.g. heatwaves, flooding), are already felt and will only become more common. The risks include the structural damage/ collapse of buildings, decreasing real estate value in high-risk areas due to more extreme local weather, water encroachment, deteriorating indoor climate and reduced building lifetime. Establishing an obligation to develop detailed adaptation plans is an opportunity to create synergies with mitigation strategies.

Why: Extreme weather conditions such as heatwaves and floods are increasing in intensity and frequency. To make sure the building stock is ready to confront these conditions, building simulations at both the design and operational stage should use weather data on future expected impacts. Today simulations are based on historic weather data.

How: The EU currently has a strategy on adaptation which "aims to make Europe more climate-resilient. By taking a coherent approach and providing for improved coordination, it aims to enhance the preparedness and capacity of all governance levels to respond to the impacts of climate change." The strategy does this by promoting actions by the Member States, promoting better-informed decision-making, and promoting adaptation in key vulnerable sectors. It refers to buildings in its accompanying document "Adapting infrastructure to climate change" (SWD/2013/0137 Final), however, on a very general level only.

The EU's adaptation strategy and the work of the Covenant of Mayors have (by November 2020) led to 1,505 commitments/strategies by local authorities which include adaptation considerations.[46] While this development is significant, this policy action suggests a stronger requirement where all local authorities need to develop a strategy that assesses the vulnerability of the building stock and develop actions to increase resilience in the built environment. This could be done through a requirement for the Member States in the EPBD.

Links with existing and other suggested actions:

- Can be combined with action 1b and 6b.

Existing cases

- Rotterdam Adaptation strategy is a detailed strategy with several measures for the built environment, including the concept of "flood-proofed" buildings.
- Slovenia's latest LTRS includes the aspect of resilience for earthquakes in describing its long-term plan for the building stock.[47]
- The Home Quality Mark in the UK provides impartial information from independent experts on a new home's quality and sustainability. It clearly indicates to households high standards for running costs, health and wellbeing benefits, and environmental footprint associated with living in the home. In

[46] See CoM action plans (Available: Website).
[47] Interviewee input.

short, it helps everyone to fully understand the quality, performance and attributes of a new-build home.

Impact consideration of Policy Action 1.3

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	W Weaknesses	O Opportunities	T Threats
Local plans can involve and engage stakeholders and increase awareness Adaptation measures are primarily local	Lack of implementation guidance and national targets	Include a broad range of stakeholders in the planning process Take into consideration key concepts for mitigation in the building sector	Difficult to monitor measures

Policy action 1.4: *Revise the cost-optimal definition to incorporate all renovation-related benefits*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Revision of cost-optimality definition to fully reflect external costs and benefits.

Why: The cost-optimality calculation has been established to allow the Member States to define minimum energy performance requirements within the boundary of cost-optimality, taking into account parameters such as climatic conditions and the practical accessibility of energy infrastructure, and compare the results of this calculation with the minimum energy performance requirements in force. With the introduction of clear long-term targets for GHG emission reductions and progressive mandatory minimum energy performance standards, the methodology requires a review to allow full integration of all benefits of mandatory and voluntary measures. This will support the national definition of minimum mandatory requirements and the introduction of other support measures for renovation. Concerning the evolution of national NZEB standards towards energy-positive building standards, the cost-optimality approach should also evolve to reflect changing decision-making parameters.

How: Revise the cost-optimality calculation to fully take into account externalities such as the avoided cost of carbon emissions and benefits on climate resilience, health and wellbeing. The measure needs to be accompanied by increased financing directed to those actions that are financially viable only in the long term, as well as to households with low income.

When: Including in the planned EPBD revision.

Impact consideration of Policy Action 1.4

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Accounting for the wider benefits of energy renovation, including improved health, productivity and wellbeing	Low acceptability among stakeholders and public policymakers due to path dependencies Lack of quantified data on health and wellbeing	Mandating a deeper level of renovation Accelerating measures that have previously not been "cost-optimal"	Increase in costs of renovation Low social acceptability Difficulty in obtaining robust results if unprecise data or coefficients are applied

3.4. Cluster 2: Regulatory and market-based instruments for a transformation of the European building stock

An evaluation of the Member States' LTRS shows a policy gap in the current and planned policy mix towards reaching climate targets. The EU Commission's impact assessment on a new climate target (SWD(2020) 176 final) shows that the building sector needs to reduce energy-related GHG emissions by 60% compared to 2015.[48] In view of an expected higher GHG emission reduction target for the EU, it becomes even more obvious that the existing policy mix is not sufficient to steer the needed transformation. Existing policy instruments such as grant and loan schemes will have to be massively stepped up as well as their ability to trigger investments, while new policy instruments will have to be established.

Mandatory minimum energy performance standards (MEPS) for existing buildings can ensure that the worst-performing buildings are upgraded. If renovation up to a certain performance threshold (e.g. based on the EPC label) becomes mandatory, it avoids the split-incentive dilemma, one of the largest obstacles to increasing the renovation rate. MEPS need to be designed based on progressively increasing requirements to make sure long-term objectives are met. MEPS ought to be accompanied with tailored renovation advice, such as the building renovation passport, to avoid technical and economic lock-in effects.[49]

Carbon pricing can be a very powerful tool to contribute to decarbonising the building stock if the price signal is high enough to support the business case for low-carbon investments. However, as a majority of barriers to energy renovation of buildings is primarily non-economic, the coherence of carbon pricing alongside other relevant policy tools (e.g. MEPS) is crucial to stimulate building renovation.

Several regulatory and market-based measures have proved to be impactful, such as revised public procurement rules to better foster deep renovations, use of recycled materials, digital solutions (e.g. BIM), climate resilience and accessibility for disabled people. Regulatory approaches have also shown to be impactful in ensuring a proper indoor environment.

The policy actions proposed in this chapter have been derived and designed to complement each other. However, they could also be implemented as standalone measures. Action 2.1 is setting a long-term price signal for CO_2-emissions helping to re-evaluate the costs of renovation measures, e.g. those required under a MEPS scheme, the proposed action 2.2. Action 2.3 is proposing minimum mandatory green procurement criteria to put the public sector in a front-runner position to create a market for sustainable renovation solutions. Similarly, action 2.4 helps prioritise schools and hospitals to profit from better indoor environmental quality. Action 2.5 proposes the introduction of a requirement for the inspection of standalone ventilation systems in residential buildings, pushing for widespread deployment of better indoor air quality solutions.

[48] Climact, Ecologic Institute (2020). Analysing the impact assessment on raising the EU 2030 climate target - How does the European Commission's approach compare with other existing studies? (Available: Online).

[49] The energy savings which are not going to be realised due to unambitious and insufficiently stringent energy requirement targets for buildings, building elements and equipment (IEA Glossary).

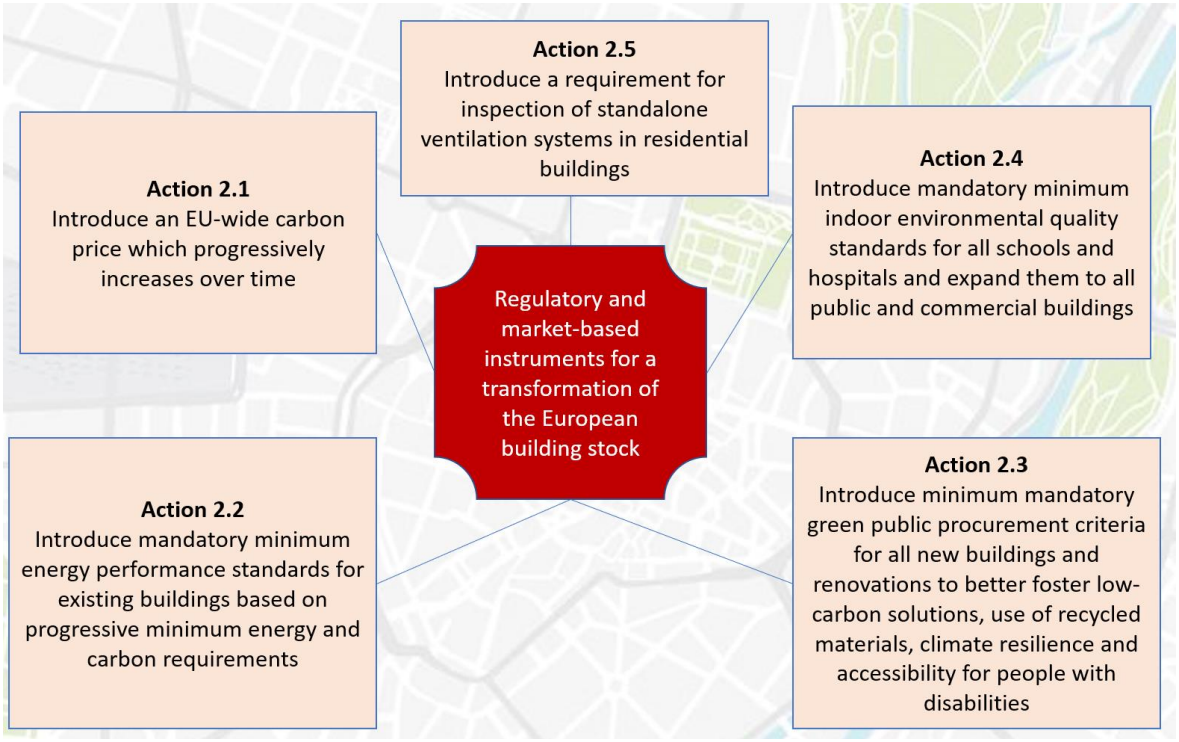

Figure 7: Policy actions in Cluster 2: Regulatory and market-based instruments for a transformation of the European building stock

Policy action 2.1: *Introduce an EU-wide carbon price which progressively increases over time*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Introduce a carbon price on road transport and heating fuels. In addition, a levy could also be imposed on certain building materials with high carbon and environmental impacts, such as steel, concrete and sand.

Why: A higher cost of emitting carbon would make investments in energy efficiency and renewables more economically viable. It would also ease the imputation of avoided costs of carbon emissions in the cost-optimality calculation (see action 1.4).

Carbon-intense building design, including construction material use, is often used because it is cheaper than low-carbon alternatives. A carbon price would incentivise consideration of low-carbon building design, encompassing structural building design principles, selection of low-carbon and resource-lighter renewable and abiotic materials, the use phase of the building as well as longevity and adaptability of buildings for multiple uses. In this context, although only relating to construction material choice, considering a levy on carbon-intensive construction materials could contribute to correcting the above-mentioned market distortion and thus form part of a policy approach towards using carbon pricing. One way to reduce the total carbon emissions from the sector is to use materials that have lower embodied emissions. A levy would deter the construction industry from using materials that have high embodied emissions while providing a public revenue stream.

How: Expansion of the scope and review of the Energy Taxation Directive (2003/96/EC), which for now las down the European rules for the taxation of energy products used as motor fuels or heating fuels and of electricity. The review of the Energy Taxation Directive should be accompanied by other measures/revenue recycling, such as property tax reductions and other incentives for tenants to prevent a worsening of the split-incentive dilemma. The European Commission favours the extension of the existing EU ETS (Directive 2003/87/EC) or the setup of a new scheme for buildings.[50] The introduction of carbon prices provides MS with the opportunity to use the ETS revenues to finance buildings renovation schemes.

When: A revision of the Energy Tax Directive (2003/96/EC) is expected b June 2021. Proposal of the European Commission on the review and possible extension of the EU ETS (Directive 2003/87/EC) to buildings and road transport to come in June 2021.

Links with existing and other suggested actions: Reform the cost-optimality calculation as suggested in action 1.4. and introduction of the MEPS scheme (action 1.2). A carbon price and its full consideration in the cost-optimality calculation will help to make the required renovations under MEPS more cost-effective. At the same time, MEPS will secure that the worst-performing buildings are renovated, while avoiding a preference of only supply solutions for decarbonisation.

[50] European Commission (2020). Stepping up Europe's 2030 climate ambition. Investing in a climate-neutral future for the benefit of our people, COM(2020) 562 final.

Existing cases:

- Carbon taxes exist in the several Member States (Sweden and Finland currently have the highest ones)
- A national ETS for buildings and road transport will start in 2021 in Germany.
- The UK "Aggregates Levy" which imposes a tax on sand, gravel and rock with a certain environmental footprint.

Impact consideration of Policy Action 2.1

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Internalises the negative impacts of carbon emissions Incentivises low-carbon solutions Revenues can be used to reduce the social impacts on the energy poor	It can be difficult to price externalities and thus also to set the carbon tax level; risk that tax levels may be set at arbitrary levels to ensure acceptability and accompanied by exemptions Low public and political acceptance, especially if the tax level reflects externalities Low potential to address the majority of barriers to energy renovation that are largely non-economic	Incentivise low-carbon solutions throughout all sectors Ensure a level playing field between electricity and fossil fuels used for heating and transport	Companies might mask their true carbon emissions and find loopholes to circumvent it Risk of carbon leakage in the absence of a proper carbon border adjustment mechanism Risk of adverse effects on affordability and energy poverty, if not accompanied by appropriate measures

Policy action 2.2: *Introduce mandatory minimum energy performance standards (MEPS) for existing buildings based on progressive minimum energy and carbon requirements*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: MEPS is a regulatory requirement mandating buildings to meet a defined performance threshold, by a specified compliance date or according to natural trigger points in the building's lifecycle (e.g. time of sale). MEPS can apply to all buildings or particular building segments.

For residential buildings, the policy action suggests the EU first introduce MEPS based on operational energy use (kWh/m²/year), to utilise the existing policy infrastructure, especially the current EPC schemes. The MEPS should then evolve to also consider the operational carbon performance (CO_2/m²/year) to align the requirement with the long-term climate target. By combining the two metrics, it will be possible to ensure a minimum building performance level, which is essential to ensure a decent living standard for all Europeans, while the route to a "future-proof" building can optimise the balance between energy efficiency and renewable heating.[51]

For non-residential buildings (alternatively, larger buildings), the policy action suggests the real operational carbon is used to set the threshold. The carbon performance is derived from the actual energy consumption (e.g. as displayed by smart meters) and the local energy mix, which is "normalised" based on the building's use, number of occupants, weather etc.[52]

Why: MEPS has the potential to drive renovations when implemented effectively and with clear timelines. A progressively tightened requirement could help operationalise the objective to have a highly efficient and decarbonised building stock by 2050.

How: Introduce requirement of MEPS in the upcoming EPBD revision, including a long-term trajectory of how the requirement should be tightened. If alternative options are considered, they should be very concrete, measurable, additional to existing measures and outperforming the MEPS to make sure the targets are achieved.

A MEPS pathway (Policy Pathway 2 in Annex IV) can evolve into progressive minimum carbon performance requirements (expressed in CO_2/m_2/year and relating to operational energy consumption). For residential buildings, the pathway foresees that EPCs are updated to feature the carbon performance of the building more reliably. For non-residential buildings, the carbon performance is derived from the actual energy consumption (e.g. as displayed by smart meters) and the local energy mix.

When: Introduce in the proposal for EPBD revision planned in 2021. Public and larger non-residential buildings should be obliged to comply with the standard a couple of years before the residential sector. See timeline in Policy Pathway 2 in report on MMR (Annex IV).

[51] Several existing EPCs already display the building's CO_2 footprint.
[52] New York City's Law 97 sets annual carbon intensity limits on building emissions for larger buildings. See Annex IV for more details.

Links with existing and other suggested actions:

MEPS will become relatively less expensive if supported by a carbon price (action 1.1.). The reliability, availability and scope of EPCs (see 3.1) are vital to improving, as they will facilitate the introduction of MEPS. Digital building logbooks (3.4) and building renovation passports (3.2) have also been identified as instruments that will contribute to the effectiveness of MEPS.

The findings of this study clearly show that regulatory actions should be combined with incentives for more ambitious measures. While the EU Taxonomy Regulation for sustainable activities can steer investments towards high-performing buildings, MEPS should pull upwards the bottom tier (i.e. worst-performing buildings) progressively. The two policy instruments ought to be aligned, the taxonomy rewarding the best in class, while the MEPS raises the lower bar.

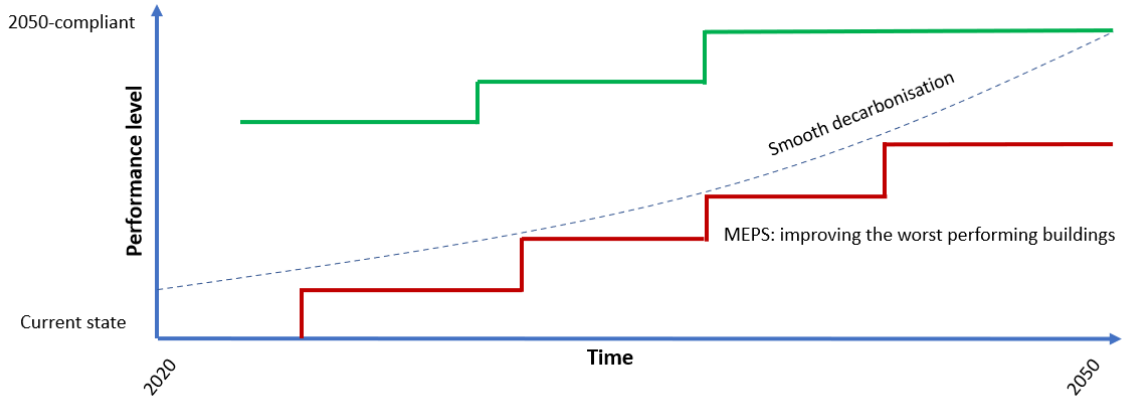

Figure 8: Coupled with the taxonomy regulation for sustainable activities, MEPS can be an effective tool to make the sector climate-neutral by 2050

Existing experiences: MEPS have already been implemented in various jurisdictions for this purpose, especially across Europe and the United States. For example, the UK, France, the Netherlands and Belgium (Flanders and Brussels) have implemented, or have far-reaching plans to implement, MMR for existing buildings.

See more in the separate report on MEPS (Annex IV).[53]

Impact consideration of Policy Action 2.2

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

[53] See also reports by Sunderland, L. et al. (2020) Filling the policy gap: Minimum energy performance standards for European buildings (Available: Online); Nadel, S. & Hinge, A. (2020) Mandatory building performance standards: A key policy for achieving climate goals (Available: Online); Hinge, A. (2020) International review of minimum energy standards for rented properties. (Available: Online).

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Targets the worst-performing buildings Progressive tightening of standard towards the long-term target Providing a phased introduction allows market actors time to prepare and may improve compliance	Lack of reliable EPCs can undermine the MEPS An obligatory investment requirement might not be considered cost-effective from a purely financial perspective Dependent on detailed statistical data on building stocks and financial support for renovation	Data collection Impact could be increased by leveraging voluntary initiatives and pledges on minimum performance	Improving the reliability of EPCs has proven to be tricky Risk of adverse effects on affordability and energy poverty, especially if not accompanied by adequate and accessible financial support Risk of low social acceptance (if policy not accompanied by supporting measures)

Policy action 2.3: *Introduce minimum mandatory green public procurement criteria for all new buildings and renovations to better foster low-carbon solutions, use of recycled materials, climate resilience and accessibility for people with disabilities*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Public procurement can be summarised as the purchase of products or services by a public sector organisation or body. To ensure transparency, non-discrimination, equal treatment of all competitors and that the best offer is selected, public administrations have to follow some procedural rules (at EU level, these are established in the 'public procurement directives' Directive 2014/24/EU and 2014/25/EU). In some cases, general rules may also exist that ensure products purchased correspond to certain standards, like high energy efficiency performance rules in the EED.[54] Procurement rules should also not only link to the performance level but to 'healthy' materials, of low toxicity and emissivity, which could be derived from energy product declarations. Public procurement rules can also be used to ensure a construction project considers climate resilience and accessibility for the disabled.

The Circular Economy Action Plan mentions Level(s) as a framework for construction and buildings to increase sustainability, with important implications for areas such as green public procurement. The findings of this study show that this would be an important step. Dedicated technical and legal training for procurement officers, as well as standard measurement and reporting practices, would also foster a broader use of green procurement.[55]

Why: Public procurement ought to be aligned with EU and Member States' long-term policy objectives. The public sector has a crucial role to play as it represents a significant market share: green public procurement criteria incorporating the Level(s) indicators have the potential to drive change in the market. The choice public authorities make when purchasing products and services is an important policy instrument to promote energy efficiency and healthy materials and achieve energy savings, while minimising the whole-life carbon impact.

How: The European Commission's Circular Economy Action Plan (CEAP) states that "the Commission will propose minimum mandatory green public procurement (GPP) criteria and targets in sectoral legislation and phase in compulsory reporting to monitor the uptake of Green Public Procurement (GPP) without creating unjustified administrative burden for public buyers. Furthermore, the Commission will continue to support capacity building with guidance, training and dissemination of good practices and encouraging public buyers to take part in a 'Public Buyers for Climate and Environment' initiative, which will facilitate exchanges among buyers committed to GPP implementation".

The findings of this study support this step. It is especially important to use this instrument to bring cross-sectional investments in sustainable solutions.

The review and possible extension of the Energy Efficiency Directive EED (Directive 2012/27/EU), Article 6 could play a major role to implement the action.

When: Launch the GPP criteria in suitable directive or directives, such as the EED (in which Article 6 sets out "that central governments purchase only products, services and

[54] http://eedguidebook.energycoalition.eu/public-procurement.html
[55] Dodd, N. et al. (2016). Green public procurement criteria for office building design, construction and management. European Commission. (Available: Online).

buildings with high energy-efficiency performance") or in one of the EU's public procurement directives.

Impact consideration of Policy Action 2.3

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	W Weaknesses	O Opportunities	T Threats
Government procurement is worth around 20% of the EU's GDP	Most procurement at local level, where budgets are often tight Offer of products and services at local level could also be limited (at least at the beginning) Procurement officers may need training for a proper application of new rules	Public procurement can be exploited to create a market for green and sustainable solutions Link with Level(s) and Taxonomy regulation for sustainable activities	

Policy action 2.4: *Introduce mandatory minimum IEQ standards for all schools and hospitals and expand them to all public and commercial buildings*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Inadequate and unhealthy indoor environments are a problem throughout Europe, causing lower productivity and wellbeing, health issues and immense social costs. Two groups that are especially sensitive to a bad indoor environment are children and sick people. Addressing all school and healthcare facilities would improve the learning (and wellbeing) of children and reduce healthcare costs while establishing the importance of the indoor environment for our health and wellbeing.

Why: A meta-study of the impact of indoor environmental quality suggests that a healthy indoor environment accelerates the educational performance of students by up to two weeks a year and speeds up recovery time in hospitals by more than 10%.[56] The Renovation Wave presents a key opportunity to invest in people alongside improving building performance.

How: Introduce a requirement where all Member States should ensure a healthy indoor environment in schools and hospitals. Subsequently, the requirement should be expanded to all public and commercial buildings. This can be done in conjunction with Article 5 of the EED, which sets out the renovation of 3% of all central government public buildings per year. The efforts should be accompanied with systemic research (e.g. through Horizon Europe) measuring the impact of the renovation, before and after improvement, on learning abilities, health and general wellbeing.

Introduce in LTRS a strong recommendation to recognise increased comfort, health and productivity as drivers for energy renovation. Policies and measures should ensure adequate levels of natural lighting, acoustic comfort, ventilation, thermal comfort and indoor air quality. Incentives for renovation should include indoor environment parameters as well as energy savings to promote projects that also aim to improve health and wellbeing.

When: Introduce a requirement for mandatory minimum IEQ standards in upcoming EPBD revision (planned for 2021), with links to Article 2a of the same directive and Article 5 of the EED (2021).

Impact consideration of Policy Action 2.4

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

[56] Buildings2030 & BPIE (2018) Building 4 People – Quantifying the benefits of energy renovation investments in schools, offices and hospitals. (Available: Online).

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Improve learning and health in building segments where the effects would be the largest Can be a driver for deep renovation in the respective building segments	Synergies with other strategic areas are few	Showcases the multiple benefits of improved IEQ Triggers deployment of technologies and practices in other segments as well Could upskill workforce and generate employment Could earmark public investments to revive the construction market by focusing on creating value for people and alleviate poverty Link to lower risk of airborne diseases Increased safety in socially relevant buildings	Limited funds and capacity in local authorities

Policy action 2.5: *Introduce a requirement for inspection of standalone ventilation systems in residential buildings*

What: Mandatory initial inspection of new ventilation systems in residential buildings after their installation, performed by a certified inspector. For existing buildings, ventilation control must be carried out regularly (e.g. every five years). The certified expert should provide suggestions on how to reduce energy consumption for ventilation without this giving rise to a poorer indoor environment.

There are two main reasons for the poor performance of ventilation systems:[57]

1. Modifications in the performance of the ventilation system itself (due to actions by users, ageing of the system, poor maintenance, etc.)
2. Poor operation of the ventilation system (due to problems such as noise or draught, energy conservation concerns, etc.).

Why: Occupants should benefit from this inspection, which focuses on the ventilation system's energy performance, airflow rates/air change and hygiene. As 93% of standalone ventilation systems are installed in residential buildings, this action suggests focusing on this building segment.[58] By checking the effectiveness of the existing ventilation system and how users are operating it, it will be possible to improve both energy efficiency and indoor air quality levels.

How: Introduce a legal requirement for regular inspections, in relation to EPBD Articles 14-15.

- Increasing users/owners' awareness can contribute to maintaining the performance of ventilation systems. Communication towards professionals can also contribute to improving their knowledge/know-how, thus improving the quality and performance of ventilation systems.[59]
- Supporting the effort through practical training of installers will increase the quality of their work. The training could be linked to mandatory certification of installation companies.

When: Introduce in the revision of EPBD.

Existing cases:

- Obligatory ventilation control for housing is taking place in Sweden. This applies to all buildings and must be regularly performed to check if the indoor climate is good and the ventilation systems are functional.[60]
- In France, VIA-Qualité guidelines exist for housebuilders on how to improve indoor air quality. The quality approach includes checks and measurements.[61]

[57] Durier, F. et al. (2020) Technical study on the possible introduction of inspection of stand-alone ventilation systems in buildings. European Commission. (Available: Online).
[58] Ibid.
[59] Ibid.
[60] Boverket (2019) Obligatory Ventilation Control (Available: Website).
[61] Cerema (2018) VIA Qualité (Available: Website).

Impact consideration of Policy Action 2.5

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Improves the effectiveness of existing systems Better air quality will reduce overall healthcare costs Creates local jobs	Regular checks come with a considerable cost	The ongoing Covid-19 pandemic will influence the role of (home) offices and where we work – better indoor air quality at home and at the workplace will become even more important	Importance of clear and manageable specifications for ventilation checks

3.5. Cluster 3: Enhance the gathering, availability and harmonisation of building data and information

Data is key for any policy instrument to decarbonise the building sector. It helps to understand where policy efforts are needed, allow for tailor-made renovation services, prove efficiency gains and raise consumers' awareness of their own consumption behaviour. However, there is a considerable lack of reliable and granular data on the performance of the EU building stock, including general data (age of the building, how it was built), building characteristics, actual energy consumption data. These types of information would provide for a better understanding of the building stock and allow for better and more effective policies to be developed.

Only around 10% of buildings in Europe possess an EPC and the quality of EPCs varies considerably across the EU. It is necessary to improve reliability and increase the scope of EPCs to include and display a building's CO_2 performance, history and a more likely outlook of its energy use and demand-side flexibility readiness. Upgrading EPC databases[62] is important to improve understanding of the overall performance of the built environment.

The EU should mandate the Member States to introduce building renovation passports as an advisory tool, providing stepwise advice to a "future-proof building", including improvement of the efficiency level, the share of renewables and flexibility/smartness, while minimising the whole-life carbon footprint. In order to be able to take into account whole-life carbon in policy instruments such as MEPS, a first step is to introduce requirements on assessing and reporting on lifecycle aspects, starting with new and public buildings and then progressively widening the scope towards other types of buildings.

To support this data collection effort, which would also allow for better planning of action at a district level, Member States should be mandated to make building-related data available and attainable in a digital building logbook. This should include data on building materials, their carbon content and climate resilience.

Finally, more data needs to be generated on the additional benefits of energy renovation. If quantified and increasingly measured, this would allow for a redefinition of the cost-optimal renovation levels, incorporating all renovation-related benefits including health and wellbeing.

The actions proposed in this cluster are proposing to improve and widely deploy main instruments providing data on the building stock and individual buildings, i.e. EPC (action 3.1), building renovation passport (action 3.2), digital building logbook (action 3.4). In order to phase-in the consideration of whole life carbon emissions, action 3.3 proposes to introduce a requirement for assessing and reporting on lifecycle aspects.

[62] Several Member States have advanced and dynamic databases, such as Portugal, Denmark and Ireland. Evidence from these countries shows that there are many benefits from the advanced databases, such as better empirical data to base policymaking on, encouraging renovation investments (e.g. through links with one-stop-shops) and simplifying compliance checking for EPCs.

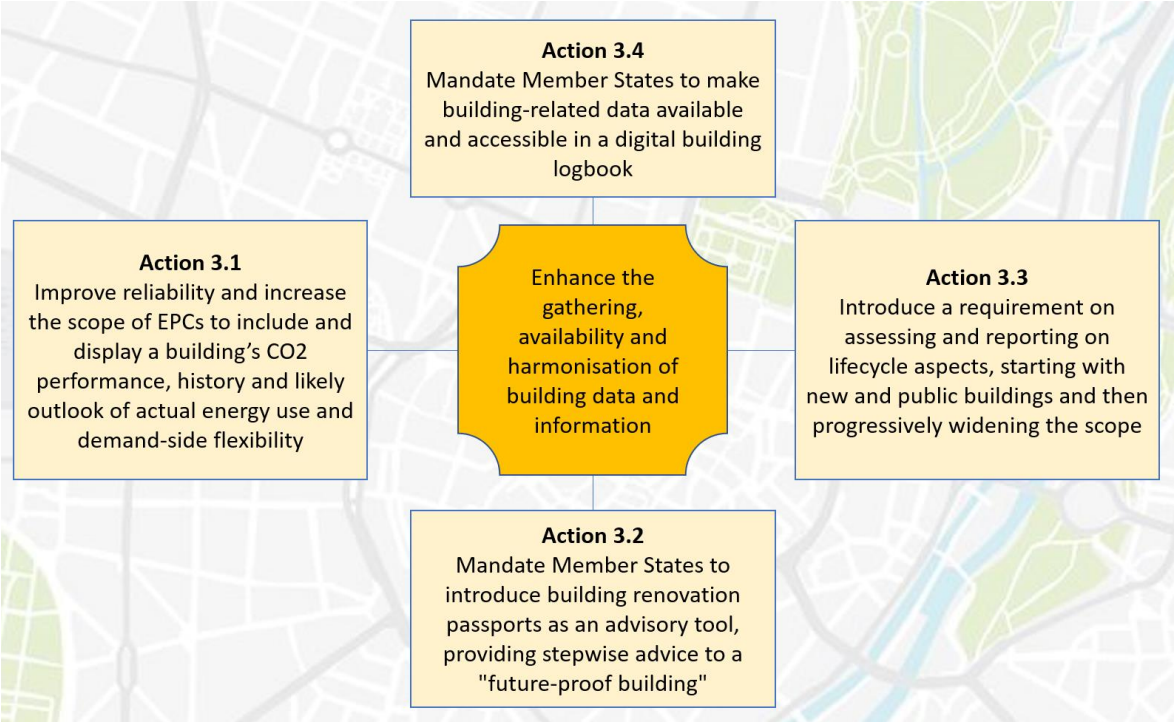

Figure 9: Policy actions in Cluster 3: Enhance the gathering, availability and harmonisation of building data and information

Policy action 3.1: *Improve reliability and increase the scope of EPCs to include and display a building's CO_2 performance, history and likely outlook of actual energy use and demand-side flexibility*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: EPCs were first introduced by the EPBD in 2002 [2002/91/EC] with the aim to make the energy performance of individual buildings more transparent. The EPBD recast in 2010 [2010/31/EU] reinforced the legislation by introducing independent quality control of EPCs, penalties for non-compliance, the obligation to display the energy label in advertisements, a mandatory requirement to hand out a copy of the EPC in the sale and rental transactions and improvement of featured recommendations. The EPBD amendments in 2018 [2018/844] strengthened the provisions again by setting out that the Member States should provide information to owners and tenants on the purpose and objectives of EPCs, energy efficiency measures and supporting financial instruments through accessible and transparent advisory tools such as direct advice and one-stop-shops. The Renovation Wave strategy declared the EPC requirements will be strengthened again.

In addition to the proposed improvements in the Renovation Wave regarding reliability, comparability, data gathering and storage of the certificates, this action proposed an incremental improvement of how data is gathered and displayed:

- CO_2 performance would increase the awareness about the building's carbon footprint; this is already possible now[63] and is planned or implemented in several Member States, such as Germany and France.
- History and likely outlook of actual energy use would give a better indication of the evolution of the energy needs of the building.
- Demand-side flexibility would allow the buyer to assess if the building can be managed proactively to participate in the energy market.

Why: The new indicators would improve the usefulness and the demand for the certificate.

How: Mandate Member States to measure, store and display the additional information on the EPC. The demand-side flexibility indicator should draw from the optional smart readiness indicator.

When: Introduce the requirements in the upcoming EPBD revision (planned for 2021).

Impact consideration of Policy Action 3.1

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

[63] Under the EPBD, Member States already have the possibility to define additional numeric indicators to express the energy performance of buildings, including in terms of greenhouse gas emission produced in $kgCO_2eq/(m^2*y)$, in addition to primary energy use.

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Adds indicators which bring valuable information to homeowners and buyers It is already possible to implement the suggested indicators Gives buyers a better idea of energy needs Links energy efficiency and climate footprint if expressed properly	Additional indicators might increase the cost and complexity which could be affecting user acceptance and degree of comprehension/ usefulness	Enables demand response Incentivises micro-energy hubs, enabling cheaper and green electricity for electric vehicles and electric bikes Enables financial schemes and regulations, targeting EPCs, to focus on carbon emissions instead of just kWh	Makes the certificate more complex and possibly more difficult to communicate

Policy action 3.2: *Mandate Member States to introduce One-sports as an advisory tool, providing stepwise advice to a "future-proof building", including improvement of the efficiency level, indoor environment, share of renewables and flexibility/smartness, while minimising the whole-life carbon footprint*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Definition of the building renovation passport in the 2019 EPBD19a feasibility study: "A building renovation passport provides a long-term, tailored renovation roadmap for a specific building, following a calculation based on available data and/or an on-site audit by an energy expert. The instrument identifies and outlines the deep renovation scenario(s), including steps to implement energy-saving measures that could improve the building's energy performance to a significantly higher level over a defined period. The instrument can be complementary to energy performance certificates and/or combined with digital logbooks."[64]

The building renovation passport could provide a comprehensive set of relevant indicators (e.g. energy consumption, CO_2 emissions, thermal and acoustic comfort, climate resilience, indoor air quality, daylight, as well as level of accessibility for disabled people). It could also include a dynamic dimension by delivering information about recommended improvement strategies in a detailed way, stimulating deep or staged deep renovations while considering the whole-life carbon impact of the alternative renovation steps.

Why: Deep renovation is a complex process that involves a complete overhaul of the energy performance of a building. Most people are aware that better insulation of walls, roofs and basements will lower the energy consumption of the household. However, many people are not aware of issues like air leakages,[65] allowing heat to escape the building through weak points in the building envelope. Achieving a successful deep renovation requires expertise and careful detailing and sequencing of the renovation measures, especially when a deep renovation is achieved in several stages. The building renovation passport can facilitate this by providing a tailored renovation roadmap for a specific building, which can be carried out in one stage or multiple steps over several years.

The building renovation passport should be based on a detailed energy audit, which also opens up the opportunity to integrate whole-life carbon considerations and to address how the renovation steps can improve the smartness of a building, its climate resilience, its indoor environment and accessibility for disabled people.

How: The EU actively promotes the idea of building renovation passports, as complementary to the EPC, and proposes their introduction to complement EPCs in the next EPBD revision in 2021. The building renovation passport can be a voluntary, preferably subsidised, service to the mandatory EPC, which also would drive the uptake of EPCs.

The building renovation passport should be introduced in a wider policy framework where it's accompanied by financial measures and training schemes for the experts. In addition, the European Commission could support this by:

- Establishing a technical assistance facility assisting Member States to introduce a financial bonus that is triggered when a certain percentage of stages in the

[64] Fabbri, M. et al. (2020). Technical study on the possible introduction of optional building renovation passports. European Commission. (Available: Online).
[65] Leakages often occur through junctions between walls and other walls and between walls and windows.

building renovation passport has been implemented. The bonus can be a lump sum or recoup the cost of the passport.
- Provide an open tool for Member States to copy the basic architecture of the BRP.
- Set out guidance documents on how to integrate the building renovation passport into EPCs and existing audit schemes, and how it can be combined with a digital logbook or linked to other instruments, such as financial support.

When: Introduction in the next EPBD revision in 2021.

Impact consideration of Policy Action 3.2

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Positive impact on the number of renovations, depth and quality of renovations, as well as which measures are carried out and in what sequence Avoids lock-in effects, where the cost-optimal path to a deep renovation becomes unattainable because measures were carried out in the wrong order	A good building renovation passport ought to be based on an energy audit, in which the homeowners' preferences are considered, making it more expensive	Enables more people to engage in deep renovations Subsidies can be used to incentivise people to get a passport and to carry out certain steps Can be linked and integrated with the mandatory minimum requirement and district-specific aspects such as renewable heat	Risk that people only carry out the initial step, while not pursuing all steps towards a deep renovation Finding a balance between required effort/cost and benefits

Policy action 3.3: *Introduce a requirement on assessing and reporting on lifecycle aspects, starting with new and public buildings and then progressively widening the scope*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Collecting and storing information on buildings' lifecycle emissions would increase transparency and awareness about embodied carbon. The lifecycle information should be compiled in a publicly available database, starting with public and new buildings.

Why: Expanding the optimisation of carbon standards for buildings from operational emissions to the building's full lifecycle will enable a reduction of the total carbon emissions from the sector. The requirement would aim to promote the transition towards more sustainable construction with reduced climate impact.

How: In order to cover an entire lifecycle, the requirement can be based on EN 15978 (environmental performance of buildings)[66] covering the use stage as well as the end-of-life stage.

Level(s) is a European Commission framework for improving the sustainability of buildings, based on flexibility, resource efficiency, health and wellbeing, and circularity. It is a voluntary reporting framework, which currently can be used by all stakeholders in the building and construction value chain. Level(s) brings together several European standards and can therefore be the common method to account for the carbon and environmental performance of the built environment.

BIM could enable construction professionals to quantify the embodied environmental impact and lifecycle cost performance of buildings. Level(s) can further support BIM developments and project planning by facilitating a framework for how embodied carbon can be accounted for.

When: Promote life-cycle reporting (e.g. Level(s)), possibly in the context of the EPBD revision, to allow for assessing and accounting of embodied carbon in segments such as new and public buildings. Member States could be asked to integrate it in public procurement requirements (with links to task 2.3).

The EU revision of the Construction Products Regulation ought to require specific climate data/environmental data for construction products, in order to simplify this requirement and make it more effective.

Existing cases:

- Reporting on lifecycle emissions in the built environment is still a niche idea but we have seen a rapid increase of policies and initiatives at national, regional and city levels. Lifecycle analysis[67] is a proven method, even if its market penetration has been limited in most Member States[68]. While most existing whole-life carbon

[66] The standard specifies a calculation method based on LCA and other environmental information to assess the environmental performance of a building. This approach to the assessment covers all stages of the building life cycle and is based on data obtained from EPD, their "information modules", etc.
[67] A lifecycle analysis (LCA) is an environmental assessment covering the entire lifecycle of a product or service.
[68] See e.g. Gervasio, H. & Dimova, S. (2018) Model for life cycle assessment (LCA) of buildings. EU Joint Research Centre (Available: Online).

standards are considered too "high level" by industry professionals, some are already considered operational and commonly used.[69]

- Finland's Ministry of the Environment has developed an assessment method and will develop a generic emission database. The database will cover all main types of products and materials, sources of energy, modes of transportation as well as other main processes such as site operations and waste management.[70]
- Sweden is planning to introduce a climate declaration for all new buildings by 2022. The declaration will show the building's full carbon footprint during its construction phase, including emissions related to materials, building components and transport.[71]
- France has developed a certificate for buildings taking into account both the energy and the carbon performance of the building and displaying both. The carbon performance evaluates the impacts of the building over its entire lifecycle.[72]
- Private certification tools, such as BREEAM, LEED, HQE, SBTool, DGNB, all measure buildings' performance, also in terms of sustainability.

Impact consideration of Policy Action 3.3

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings				■	
CO_2 emission savings					■
Increased renovation rate and depth			■		
Reduction of energy poverty		■			
Improvement of health and wellbeing	■				
Increased sustainable infrastructure	■				
Increased smart readiness	■				

S Strengths	W Weaknesses	O Opportunities	T Threats
Improved market information and transparency, including the building's whole life carbon impact Enhances dialogue between design, technical and financial communities Brings minimum numbers of indicators, with maximum leverage to deliver sustainability	Dependent on the training of experts and local authorities Assessing and reporting is only the first step. Requirements, which the reporting enables, will need to come at a later stage A standardised approach is needed for how the data on whole-life carbon is gathered and stored. Without a common approach, there is a	Better data also allows for better and effective policymaking, which already is the case in Sweden, Finland, France, the Netherlands where advanced building registries are used to understand a building's life cycle carbon impact While the evidence is scarce, the case of Sweden shows that the reporting requirement sets the	The cost of accurately assessing the life-cycle carbon of a building is often perceived as too high for building owners and contractors, in relation to the perceived benefits Need to define one core purpose of this requirement

[69] One example that has been mentioned by experts is RICS (2017) RICS professional statement: Whole life carbon assessment for the built environment. (Available: Online).
[70] Kuittinen, M. & Häkkinen, T. (2020) Reduced carbon footprints of buildings: new Finnish standards and assessments. *Buildings & Cities*. (Available Online).
[71] Boverket (2020) Climate declaration for buildings. (Available: Website).
[72] Batiment a Energie Positive & Reduction Carbone (Available: Website).

Tracks performance along the lifecycle Brings consistency and accountability Provides trust and investor confidence Supports communication of value based on sustainability	risk of another database which is not interoperable with other existing databases, increasing complexity	market in motion as it starts to improve what it measures Underpins certification scheme alignment, thus allowing even more comparable data Could inspire the development of a public standard for deep renovation as possible addition to the EPBD	

Policy action 3.4: *Mandate Member States to make building-related data available and accessible in a digital building logbook*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: The digital building logbook has been defined as follows:

"A digital building logbook is a common repository for all relevant building data. It facilitates transparency, trust, informed decision making and information sharing within the construction sector, among building owners and occupants, financial institutions and public authorities.

A digital building logbook is a dynamic tool that allows a variety of data, information and documents to be recorded, accessed, enriched and organised under specific categories. It represents a record of major events and changes over a building's lifecycle, such as change of ownership, tenure or use, maintenance, refurbishment and other interventions. As such, it can include administrative documents, plans, description of the land, the building and its surrounding, technical systems, traceability and characteristics of construction materials, performance data such as operational energy use, climate vulnerability and risk, indoor environmental quality, smart building potential and lifecycle emissions, as well as links to building ratings and certificates. As a result, it also enables circularity in the built environment.

Some types of data stored in the logbook have a more static nature while others, such as data coming from smart meters and intelligent devices, are dynamic and need to be automatically and regularly updated. A digital building logbook is a safe instrument giving control to users of their data and the access of third parties, respecting the fundamental right to protection of personal data. Data may be stored within the logbook and/or hosted in a different location to which the logbook acts as a gateway."[73]

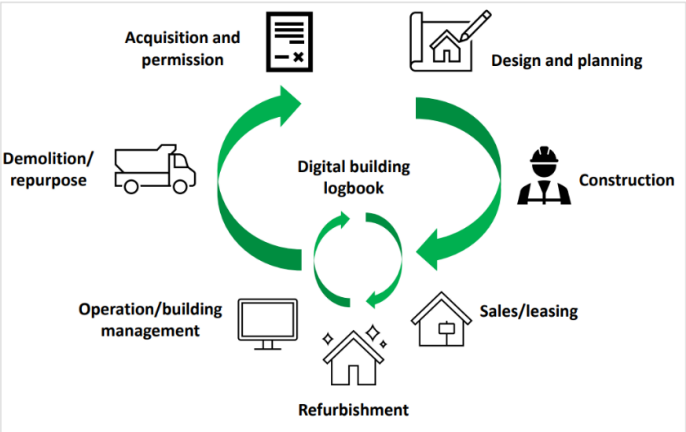

Figure 10: One logbook integrating all building-related data over the whole lifecycle of a building[74]

Why: The digital building logbook can reduce the siloes between different building-related databases and make sure the right information is available for the right user at the right time. Studies suggest that the construction sector is underdeveloped in terms

[73] Volt, J., Toth, Z. et al. (2020) Definition of the digital building logbook. European Commission (Available: Online).
[74] Ibid.

of overall digitalisation and data applications in comparison with other industrial sectors.[75] Building-related data (such as data of physical building characteristics, environmental performance information and real estate transaction data) continues to be scarce and of unreliable quality and limited accessibility.[76] The lack of a common data repository amounts to additional costs and inefficiencies, stifles innovation, increases risk and undermines investor confidence.

The digital building logbook can also push the sector to become more circular. By logging construction and building materials (type, quantity/amount, origin, carbon footprint, recycled content, as well as the end of life dismantling, reusing and recycling possibilities), it could not only facilitate design based on circular principles but also improve recycling, reduce waste and close loops.

How: Define the digital building logbook framework, enabling it to be operationalised. All the functionalities (e.g. links with financial services, incentives for building owners, or integration of one-stop-shops) can be built on the core logbook when this has been settled.

The European Commission should:

- Develop a standardised approach for data collection, data management and interoperability including its legal framework
- Explore how different databases and data points can be linked

See more in the European Commission's explorative study on digital building logbooks[77].

When: The Renovation Wave strategy encompasses several relevant provisions, including the proposal to introduce digital building logbooks, but also the revision of the EPBD, the review of the Construction Product Regulation (CPR), a 2050 whole-life cycle roadmap and the review of material recovery targets. These policy developments create the ideal momentum for the European Commission to further develop and implement the concept of the digital building logbook.

The recent study on the digital building logbook explores this topic and what actions the European Commission can take to support this instrument.

Impact consideration of Policy Action 3.4

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings			■		
CO_2 emission savings				■	
Increased renovation rate and depth				■	
Reduction of energy poverty			■		
Improvement of health and wellbeing			■		
Increased sustainable infrastructure				■	
Increased smart readiness				■	

[75] McKinsey (2016) Digital Europe: Pushing the frontier, capturing the benefits, (Available: Online); European Commission (2019) Supporting digitalisation of the construction sector and SMEs (Available: Online); BPIE and i24c (2016) Driving transformational change in the construction value chain (Available: Online).

[76] Hartenberger, U. et al. (2019) The building passport as an enabler for market transformation and circular economy within the built environment & SBE19 Conference Series paper; RICS (2017) Global trends in data capture and management in real estate and construction (Available: Online).

[77] Dourlens-Quaranta, S et al (2020) Study on the Development of a European Union Framework for Digital Building Logbooks – Final report. European Commission. (Available: Online).

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Logging each product used in the construction/renovation of buildings, including the exact location, facilitates future circular approaches including deconstruction, reuse and recycling. It also allows for recycling and traceability of chemicals The availability of consistent and reliable data can contribute to better design, construction and management of buildings	Many different perceptions of what the digital building logbook is and what it should be able to do	The digital building logbook can enable the creation of innovative services and business models (by allowing the owner of the data to share certain data in exchange for promotions or better deals) Due to the absence of a systematic approach to capturing, storing, analysing and organising it, valuable data and information is lost The storage of data is fragmented and scattered across several organisations (and even departments within the same organisation). Data that is collected and stored by one individual actor is not necessarily accessible and available to other actors in the value chain	Data security and privacy are considerable barriers in some Member States. One of the key challenges in finding the right arrangement for data privacy and security is the fact that EU data protection provisions are being modernised and constantly adapted Technology is developing fast, providing new data-gathering opportunities but also challenges The lack of a centralised storage location, with data often scattered across many organisations and departments, is one of the most significant challenges for a digital building logbook

3.6. Cluster 4: Facilitate the market penetration of innovative financial mechanisms

Financing remains a major barrier to increasing energy renovation to a future-proof level. While financial support generally needs a boost, the level of available funds provided by public authorities and leveraged by private capital varies across the Member States. New ways of providing finance and better utilising untapped funding opportunities, including energy performance contracting, would especially benefit from increased European support. The renovation process has to become easily accessible, so integrated renovation services (e.g. via one-stop-shops) should be established at all governance levels. Tailored to local circumstances, they may help to create a smooth renovation journey for private citizens and municipalities.

There are four key actions to facilitate market penetration of innovative financial mechanisms:

1) Action 1: Support Member States to establish national decarbonisation funds
2) Action 2: Mainstream energy performance contracting and use financial guarantees to enable deep renovation
3) Action 3: Establish a regulatory framework to enable utilities to enter the market of on-bill financing schemes and allow for transferable loans attached to the meter
4) Action 4: Support regional one-stop-shops to create a smooth renovation journey for private citizens and municipalities.

There are many ways to provide funding for renovation actions, all with advantages and challenges. They should be made available in full bandwidths to let the customer choose the most suitable option, a choice that can be simplified by one-stop-shops or other integrated renovation services that can advise on the appropriate mechanism. This would include innovative schemes such as the property assessed clean energy (PACE) loan scheme[78], with the loan attached to the property instead of the individual (more common in the US), or energy performance contracting, but also more traditional low or no interest loan schemes, grants or guarantees.

Three aspects have been found to be especially important:

1. The schemes will only be effective if enough money with the right reimbursement characteristics (in particular long payback period and low interest) is made available, reducing the perceived "hassle" for the project developer, and if the investments are the right investments, i.e. in line with the long-term climate targets in the building sector. Also, access to financing mechanisms should be a simple process for both building owners and project developers. An understanding of those deep renovation measures is therefore indispensable and the definition of a standard for deep renovation within the EPBD as being proposed by the Renovation Wave could be a key reference. Aligned with the EU taxonomy on sustainable finance, such a standard could not only influence the homeowner's choice of investments by coupling it to public financing schemes but also be a de-risking tool for private financial institutions.
2. National decarbonisation funds dedicated to investments in the built environment should be established at Member State level and managed by an independent fund manager supported by different advisors. These funds should be equipped with resources from EU funds, national budgets, and international financial institutions, for example under the Invest EU fund or

[78] PACE programs allow a property owner to finance the up-front cost of energy improvements on a property and then pay the costs back over time, with the loan being attached to the property and not the individual.

2021-2027 recovery funds. The fund could be used to offer grants, preferential and other loans, bank guarantees, and for providing technical assistance to applicants through one-stop-shops or similar facilities. Involving local banks in this financial scheme would be a key success component for implementing the fund, since their participation may significantly simplify the lending process as they already have the local network and infrastructure in place.

3. New and innovative financing mechanisms will play a key role in the EU's decarbonisation efforts, on all levels. Conventional financing mechanisms (e.g. loans, grants, private equity, project and leasing financing) have shown to be insufficient to trigger large investments in the built environment. Innovative financing mechanisms include instruments such as on-bill financing, energy performance contracting, PACE financing, energy efficiency mortgages and incremental property taxation.[79] The different mechanisms have been developed to target different barriers to renovations and market conditions.

Furthermore, while one-stop-shops are not a financing mechanism, they are vital in bringing the financial support and advice to the end-users. Most one-stop-shops combine technical and financial support while simplifying the whole "renovation journey" for the customer.

Figure 11: Policy action in Cluster 4: Facilitate the market penetration of innovative financial mechanisms

[79] Economidou, M. et al (2019) Accelerating energy renovation investments in buildings. European Commission, Joint Research Centre. (Available: Online).

Policy action 4.1: *Support Member States to set up national decarbonisation funds*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: The national decarbonisation funds could initially be dedicated to building renovation and subsequently broadened out to wider schemes covering other sectors (such as mobility, digitalisation and adaptation). The funds can be available on a national level and managed by an independent fund manager and supported by different advisors. That would enable necessary financial resources to be channelled into the fund from a variety of sources: the most important being EU funds, the national budget, ETS credits, and international financial institutions.

The fund can then be used to offer grants, preferential and other loans, bank guarantees, and for supporting technical assistance to applicants through one-stop-shops or similar facilities.

Why: Access to finance is one of the largest barriers to increasing renovation activities. An independently governed decarbonisation fund would be able to tailor grants and loans to the needs of the national market and make sure the Renovation Wave takes off. The fund could be used to support the objectives set out in the long-term renovation strategies.

How: Regarding targeted energy renovation measures, the fund should promote investment in packages of energy and resource efficiency measures, rather than in individual measures that would affect specific parts of the buildings or their HVAC/energy systems. By providing a more holistic approach, this would align the support with the long-term objectives. Involving local banks in this financial scheme would be a key success component, since their participation may significantly simplify the lending process. Specific financing solutions should be offered for district-scale renovation projects and financing should be entirely covered for vulnerable households.

When: Encourage the Member States to set up decarbonisation funds, potentially linked to the recovery and resilience plans. The expertise of the European Investment Bank should be used to support the Member States in operationalising the action. Also, the EU Horizon 2020's national roundtables on financing energy efficiency could be used as an arena to facilitate exchange on best practices.

Existing cases: The KfW programme (Germany) and New Green Savings Programme (Czech Republic) offers valuable lessons. Among other things, these examples show the huge importance of long-term planning and adequate management for the success of the proposed fund.

Impact consideration of Policy Action 4.1

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Assisting in the process of mobilising private financing from banks, especially in countries with a poor track record of this Can provide a guarantee for local banks and enable them to engage in renovation projects	Business model to involve national and local retail banks has to be attractive Training is needed to standardise and provide tools at the Member State level	Supporting the efficient use of existing grants (e.g. European Structural and Investment Funds, InvestEU)	Difficult to set up good performance-based KPIs to steer how the funds will be utilised The fund ought to be steered with little political influence, to ensure long-term stability, which can be difficult to get in place

Policy action 4.2: *Mainstream energy performance contracting and use of financial guarantees to enable deep renovations*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: The definition of energy performance contracting (EnPC) provided by the European Commission (as defined in EED 2012/27/EU) is: "contractual arrangement between the beneficiary and the provider of an energy efficiency improvement measure, verified and monitored during the whole term of the contract, where investments (work, supply or service) in that measure are paid for in relation to a contractually agreed level of energy efficiency improvement or other agreed energy performance criterion, such as financial saving."

Financing renovation measures via an EnPC addresses the significant barrier of high upfront capital costs. Although several EnPC markets are well established in the many EU Member States, such as Austria, Germany and Italy, the market maturity varies, with most countries experiencing a slow increase or stagnation since 2015.[80] A legal barrier for the public authorities was alleviated in 2017 with the revised Eurostat guidance on the accounting treatment of EnPC,[81] which improved EnPC uptake in the public sector in the many Member States. However, in the residential and tertiary sectors, EnPC financing is still underdeveloped due to a lack of awareness, lack of trust and the complexity of the system,[82] along with complex decision-making in the case of multi-apartment buildings, as one example.

Why: EnPC is an effective means to provide energy efficiency services that can bring added value to the whole value chain and empower energy end-users through innovative products and services offered by dedicated providers such as ESCOs, aggregators or energy cooperatives/communities.[83] A more dedicated application of EnPC in the market with long-term commitments secured by public financial guarantees or subsidies could enable deep renovations, in both the public and residential sectors. In addition, national associations can create standardised contracts to lessen the transactional burden of administering these contracts.

How: The growth of the European EnPC market is stagnating despite the promising business model. Stronger implementation of Article 18 of the EED (EU/2012/27) is needed to remove the remaining (non-)regulatory barriers and promote standardisation in the form of clear definitions, model contracts and quality labels. Standardised in-use monitoring and publication of real energy consumption data would increase trust from building users and improve data collection. Financial guarantees and dedicated loans for EnPC providers should be made available to incentivise deeper renovations.

When: As announced in the Renovation Wave, the new investment support programme InvestEU will provide EU guarantees to unlock private financing. By earmarking funding to provide financial guarantees for EnPC providers, long-term EnPC-financed projects can be encouraged across the Member States. With the EED revision in 2021, the Commission should strengthen and enforce Article 18, as well as further push standardisation efforts.

[80] European Commission Joint Research Centre (2019) Energy service market in the EU (Available: Online).
[81] Eurostat & EIB (2018) A guide to the statistical treatment of energy performance contracts (Available: Online).
[82] QualitEE survey (2017) (Available: Online).
[83] Ambience (2020) Analysis of directives, policies, measures and regulation relevant for the active building EPC concept and business models (Available: Online).

Existing cases:

- The Latvian Baltic Energy Efficiency Facility (LABEEF) provides long-term investments for ESCOs that implement renovation works in residential multi-family buildings via EnPC. LABEEF's standard documents provide model contracts aiming for different energy-saving levels.[84]
- The Horizon 2020 project QualitEE developed European guidelines for quality assurance of energy efficiency services and aims to encourage national quality assurance schemes to increase trust and market demand.

Links with existing and other suggested actions: Benefits from synergies with tailored one-stop-shops using EnPC-financed instruments and building renovation passports to align renovations with long-term deep renovation plans.

Impact consideration of Policy Action 4.2

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	W Weaknesses	O Opportunities	T Threats
The EnPC market is mature in several Member States and can be exploited further in other sectors benefiting from good practices Standardisation and quality labels help to improve trust	The long-term performance guarantee might scare ESCOs or other market actors from offering EnPC in the residential sector May be more challenging in some segments (e.g. rebound effect of efficiency improvements leading to limited financial savings in energy-poor households or multi-apartment blocks)	Deeper renovations and long-term commitments of EnPC providers offer a large potential for private sector investments across building segments	EnPC providers first focus on low-hanging fruits of renovation measures and achieve limited energy savings (lock-in effects)

[84] Accelerate SUNShiNE project. European Commission – Horizon 2020 (Available: Online).

Policy action 4.3: *Establish a regulatory framework to enable utilities to enter the market of on-bill financing schemes and allow for transferable loans attached to the meter*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: On-bill schemes are a mechanism by which building users can repay energy renovation interventions via their monthly utility bills. The capital for the upfront costs of energy renovation investment in the building is provided either by a utility company or a public institution (in these two cases we talk about on-bill financing) or by a third-party financial institution (referring to on-bill repayment). Several forms of OBS are well established in the US, and currently being piloted throughout the EU. If the debt is attached to the meter of the property, the repayment can be transferred in case of a change of owner or tenant.

Why: As an innovative financing instrument, on-bill schemes offer opportunities to alleviate persisting barriers to deep renovation measures in the residential building sector. These include high upfront costs, small-scale and fragmented projects and lack of project standardisation and evaluation processes.[85] On-bill schemes could offer new business opportunities for utilities, allowing them to differentiate their services and increase customer loyalty. To reduce complexities in an energy renovation, utilities should represent a single point of contact and offer integrated, standardised services and contracts to their customers. On-bill schemes, in case of transferable arrangements tied to the meter, can also alleviate the owner-tenant dilemma: by reducing the initial investment to zero, none of the parties has to invest and the repayments can be transferred to new tenants when the current ones leave. This solution works well in areas where the rental market is dynamic and there is a low risk that a dwelling remains uninhabited for a long time.

How: the Member States should enable utilities to offer on-bill renovation models to their customers and encourage transferable debts/arrangements tied to the meter.[86] On-bill financing could be supported by the proposed national decarbonisation funds. In this case, the fund would provide financing to local utilities (committed to on-bill schemes), who would, in turn, use this capital to realise the energy renovation investments in the end-users' buildings. The end-user would then use the monthly financial savings earned from the lower energy bills for paying back the loan in monthly instalments on their energy bill.

When: The expected revision of the EED in 2021 could include on-bill schemes as an extension of the energy services market (Article 18) and encourage the Member States to explore opportunities for on-bill schemes in their residential markets. The EED could require the legal framework to allow utilities to offer on-bill mechanisms to their customers. Further, on-bill schemes could be identified as a possible means of complying with the energy efficiency obligations set out by Article 7 of the EED.

[85] Ren-On-Bill reports (2020) on "The residential building renovation market in Germany, Italy, Lithuania and Spain", "Upscaling the residential sector with on-bill schemes - Replicability potential in the EU" (Available: Website).

[86] In case of supplier change, either the debt is fully paid to the original utility, or it has to be transferred to the new utility/supplier. In this second case regulatory work is needed: a possible solution identified by the RenOnBill project is that on-bill repayments could be incorporated in Distribution System Operator (DSO) fees (such as the ones used to repay/rent smart meters). DSO fees for on-bill schemes could be collected by the DSO (which is always the same in a given area) and then transferred to the utility that originally realised the investment.

Dedicated funding under the InvestEU or the proposed national decarbonisation fund could support pilot projects.

Existing cases:

Some of the most successful examples include the following on-bill financing programmes:

1. Sunshine scheme – Latvia
2. How$mart – Midwest Energy, Kansas, USA
3. Energy Efficiency Loan Programme – City of Tallahassee Utility, Florida, USA
4. EcoSave – Nelson Hydro, Canada
5. Home Energy Loan Program (HELP) – Penticton, Canada

Impact consideration of Policy Action 4.3

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Relationship with customers already established, generating trust "Meter attached" schemes can help alleviate the owner-tenant dilemma	Different business models ("tied to the meter", "tied to the user") could make model contracts and standardisation difficult In case of supplier switch, regulatory changes are needed to allow for transferability[87]	New business opportunities for energy suppliers Broadening of energy services (including fuel switch, energy storage services etc.) Opportunity to implement energy efficiency obligations where applicable	Only shallow renovations with small energy savings are implemented, especially if attached to the occupant, not to property

[87] The main barriers alleviated by on-bill schemes are the initial investment and, in the case of transferable on-bill arrangements, the owner-tenant dilemma. In general, an owner has no interest in realising investments in a dwelling occupied by a tenant, and the tenant does not have an interest to invest in it due to the temporary nature of their stay. On the other hand, owners could benefit from increased value of the renovated building/dwelling, and tenants from better comfort and lower bills. By lowering the initial investment to zero, on-bill schemes partially address this problem as neither the owner nor the tenant has to invest. If the contract is attached to the meter, the next tenant will continue paying. If the dwelling is sold, either the debt is paid to the utility in full, or passed to the next/owner tenant (with the same utility). Clearly, this arrangement can work well in areas where the rental market is dynamic and there is no risk a dwelling remains empty for a long period.

Policy action 4.4: *Support regional one-stop-shops to create a smooth renovation journey for private citizens and municipalities*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: The concept of one-stop-shops is to provide integrated renovation services for existing buildings, bringing together all the expertise and knowledge the end-user will need to carry out a renovation. One-stop-shops can be public or private organisations, or a mix, and typically offer services to private homeowners or municipalities. Many one-stop-shops have emerged in the EU in recent years, some with links to different EU programmes or regulations, such as Horizon 2020, Interreg, or the energy efficiency obligations (Article 7 of the EED). [88] The one-stop-shops are an important vehicle to turn the expertise and available finance into practical solutions for end-users.

One-stop-shops can also make use of digital building logbooks,[89] EPC databases[90] and building renovation passports[91] to deliver specific information and advise building owners on the best renovation options. While the national and local authorities play a crucial role in setting up and facilitating OSS, the EU can also play an important role: It should explore how the digitalisation of the construction sector and upgrade of building data gathering can support the services of one-stop-shops.

Why: One-stop-shops provide integrated renovation services and increase the demand for renovation solutions, as they can:[92]

- Reduce the hassle for the building owner and professionalise the renovation process, which can accelerate demand for (deep) renovations
- Increase trust and perceived reliability as they typically have a local connection
- Encourage interested, but not yet committed, energy users/asset owners to implement energy-saving measures.
- Attract new clients, who perhaps were not originally considering renovation, through increased awareness (e.g. illustrate cost savings and improved indoor environment).
- Improve the average renovation depth in terms of energy performance
- Ease the access to financing and occasionally offer better rates through collaboration with financial institutions.

How: Set out guidance documents for how one-stop-shops can be developed and successfully implemented. One-stop-shops have very different business models, which all have their benefits and drawbacks.[93] The guidance should therefore not inform

[88] Turnkey Retrofit (2020) Benchmarking of promising experiences of integrated renovation services in Europe (Available: Online); However, few have a mature business model and there is a strong need for investment support up to the breakeven (generally ~5 years).

[89] Depending on the functionalities of the digital building logbook, it could contribute with more accurate data over the building's lifecycle, making sure the one-stop-shop and linked contractors know the history of the building (what measures have been implemented in the past, materials, health hazards, etc.), provide real-time data that could enable demand response etc.

[90] In Denmark, the building registry and EPC database are used by (private and public) one-stop-shops, to allow the user to compare their building with others, get an indication of potential energy/cost savings linked to potential measures, and receive information on suitable financial support schemes.

[91] Like a one-stop-shop, the building renovation passport intends to simplify the renovation journey for the building owner. The building renovation passport can inform the one-stop-shop what measures will have to be implemented, and in which order, while the one-stop-shop can connect the building owner with right contractors and financial support to carry out the steps in the passport.

[92] Boza-Kiss, B. & Bertoldi, P. (2018) One-stop-shops for energy renovations of buildings. European Commission's Joint Research Centre. (Available: Online).

[93] Turnkey Retrofit (2020) Benchmarking of promising experiences of integrated renovation services in Europe (Available: Online).

regional authorities how a one-stop-shop should work, but help them develop a model that suits their local needs, culture and building stock.

The European Union together with the European Investment Bank could set up a technical assistance framework to which local and regional authorities could apply for financial support and technical guidance. The eligibility criteria should not require a new and innovative idea, as replicating an existing model should be the aim.

Making the one-stop-shops work in practice is key, which requires accessibility and that clients can trust the provided advice and guidance. Either physical or virtual, the one-stop-shop should offer an attractive renovation service, in which the hassles of a renovation are minimised. The services include renovation advice, building check/diagnosis, developing a renovation package, implementation of the actual measures, post-installation check, etc.

Also key is for the one-stop-shop to keep the customer satisfied, which includes aspects such as good customer service, easy-to-understand language, simplified contracts, and a single point of contact, as well as follow-up thorough the project so the customer doesn't feel abandoned.

Furthermore, a prerequisite for one-stop-shops should be their economic self-sustainability, allowing them to continue to function once public funding is depleted.

Many building owners have low trust in renovation advisors, which is one crucial barrier the integrated renovation services need to overcome. This barrier can be overcome if the advisors are linked with the one-stop-shop, which first needs to earn a good reputation. The EU could also contribute to this by setting up a dedicated training programme for these advisors. To enhance trust, also information campaigns and measures to guarantee adequate quality (e.g. labels, or a quality guarantee) could be implemented. Most of the existing schemes offer some sort of training for their workers to make sure they do provide good and reliable service:[94]

- Oktave, in France, has set up a teaching programme to improve the contractors' technical and sales expertise in deep renovations. After the teaching programme is completed, contractors are entitled to perform deep renovations. Oktave experts are also available to hire on-demand to solve complicated situations.
- BetterHome, in Denmark, trains all its installers conducting the on-site visit on how to approach the customer. Part of the installers' training focuses on how to address potential customers and get them to realise the full value of energy renovations (e.g. increased indoor comfort and air quality).

When: Launch the technical assistance programme in the coming years, so that it can be used to support the countries' EPBD implementation efforts. Links can be made with the national decarbonisation fund (Policy Action 4.1).

Existing cases: Oktave in France and SuperHomes in Ireland have been successful in promoting deep renovations, combining technical and financial support. RenoWatt in Belgium and SPL OSER in France have been successful in assisting local authorities and the renovation of public buildings.

[94] Ibid.

Impact consideration of Policy Action 4.4

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Reduces the number of contractors and makes the "renovation journey" smoother Sets quality standards for contractors, including training and upskilling activities	The one-stop-shop needs to build a reputation of quality and trust, which requires funds and time that are not always available	Can utilise other instruments, such as the building renovation passport, digital building logbook and EPC schemes and incorporate financial schemes such as energy performance contracting	

3.7. Cluster 5: Accelerate renovation and flexibility in the built environment by utilising digitalisation and automation

Technical and process innovation ideally merge towards new business models. To foster this, the EU could require public and larger new buildings to include an interoperable energy management system and strengthen the legal framework to enable demand-side flexibility in buildings, including electric vehicle charging stations, demand response and automation. Also, requirements to use BIM for larger new buildings and public infrastructure projects will boost the innovation capacity in the construction sector.

Public and private entities need to be enabled to aggregate demand for energy renovations, to facilitate higher production rates and serial renovation approaches including prefabrication on an industrialised scale.

A lack of skilled workforce to carry out the necessary modernisation of the built environment is addressed in two ways. First and foremost, an innovation boost in the construction sector and related industries will attract trained and skilled workers, where a successful roll-out also depends on these workers. Secondly, optimised processes, a reorganisation of the value chain and increased automation in production and installation will increase the average output of the labour force.

The proposed actions are touching upon each of those aspects (flexibility, digital planning, design and operation, and industrialisation) and are thus complementing each other.

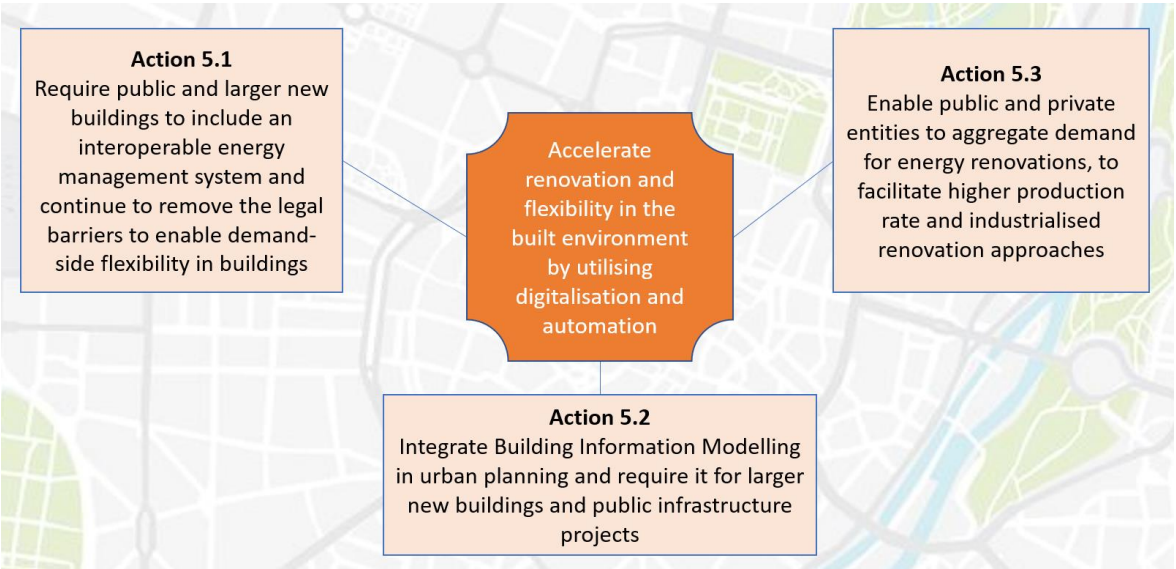

Figure 12: Policy actions in Cluster 5: Accelerate renovation and flexibility in the built environment by utilising digitalisation and automation

Policy action 5.1: *Require public and larger new buildings to include an interoperable energy management system and continue to remove the legal barriers to enable demand-side flexibility in buildings, including BACS, electric vehicle charging stations, demand response and automation*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Managing energy and other needs in buildings efficiently and intelligently can have considerable benefits. An energy management system is a method to monitor and control the energy use of a building. The system monitors and controls the energy-related components of a building, such as HVAC and lighting to minimise the energy needs and, through demand response, reduce peak loads.

Demand response is the ability to shift energy demand and avoid grid imbalance by reducing peak consumption. It can be more cost-effective to apply demand response than increase the grid infrastructure to meet demand. Instead of steering the supply side with fluctuating energy generation to balance the grid, demand response steers the energy demand of end-users by using price signals to rearrange their consumption.

Why: Buildings can balance the grid through proactive energy demand management and can play a leading role in transforming the EU energy market, shifting from centralised, fossil-fuel-based systems towards a decentralised, renewable, interconnected and variable system.

There are many benefits to fast-tracking the concept of flexible buildings: from empowering users to control their renewable energy production and consumption; to cutting energy bills and facilitating the surge of renewable energy as well as sustainable mobility.

A regulatory environment that promotes a standardised approach for demand response across the EU and assigns clear roles and responsibilities to the Member States has to be foreseen. For instance, standardised procedures to measure real-time energy consumption are needed to track the demand response services delivered by the end-users.

How: Industrial, commercial and residential consumers must have the ability to benefit from flexible demand services, otherwise smart business models will not be developed.

When: Introduce in EPBD with links to the directive on common rules for the internal market for electricity (EU) [2019/944].

Impact consideration of Policy Action 5.1

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Maximises level of building efficiency by optimising the combination between building shell and the technical systems Facilitates the growth of renewable energy, smart cities and sustainable mobility Reduces demand peaks and unlocks demand-side storage and flexibility		Allows end-users to lower their energy bills Empowers residents to become masters of their own renewable energy production and use	

Policy action 5.2: *Integrate BIM in urban planning and require it for larger new buildings and public infrastructure projects*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: BIM is a collaborative way of working, underpinned by digital technologies which unlock more efficient methods of designing, creating and maintaining our assets. BIM embeds key products and assets that can be used for effective management of information throughout a building's lifecycle. While many of its functions are mostly relevant for new buildings, renovation could benefit considerably from BIM in combination with 3D-scanning, especially in view of project aggregation and the prefabrication of renovation components.[95]

Why: BIM has many advantages, including better collaboration along the construction value chain, optimising energy efficiency, providing an overview of materials and components in the building, enabling innovative solutions (e.g. use of prefabricated facades in renovation projects) and the reuse of materials. BIM is key in activating and finding more sustainable solutions in the construction sector.

How: The Member States' LTRS could include a provision to provide information on the status of BIM, as well as the policies and actions considered to increase the use of BIM.

- Demonstrate public leadership by requiring BIM for all public building projects, which can be expanded to incorporate all larger new buildings.
- Horizon Europe programmes can be used to innovate and explore BIM applications, especially to mainstream its application for renovation.
- The potential of BIM for renovation should be addressed more prominently in the EU BIM Task Group[96] by e.g. collecting experiences on learnings from existing projects and programmes and dedicating a section in the BIM Handbook.
- Best practice exchange can showcase how BIM can be used to approach cross-sectional challenges, including the built environment, mobility, climate resilience and optimisation of the local energy system.

When: Introduce in the revision of the EPBD.

Existing cases

- Denmark: BIM has been required through public procurement processes since 2007 (starting with social housing and renovation projects and then extended to all public procurement projects). Denmark is today a leading BIM market.[97]
- France: The French government adopted a non-binding approach to allow SMEs (which represent the majority of construction companies) to implement BIM gradually and not being excluded from projects by binding public procurement criteria.98
- Estonia: "BIM adoption in the Estonian AEC Industry has increased rapidly during the last decade. One public procurer, several large construction companies and some forward-looking designers developed their in-house standards and skills to boost internal productivity and efficiency." [99]

[95] An example is the development of a RenoBIM tool within the EU Horizon 2020 BERTIM project. (Available: Website).
[96] See the work by the EU BIM task force (Available: Website).
[97] European Commission (2019) Building information modelling in the EU construction sector. Trend paper series. European Construction Sector Observatory.
[98] Ibid.
[99] EU BIM (2017) Handbook for the introduction of BIM by the European public sector. (Available: Online).

Impact consideration of Policy Action 5.2

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Streamlines the construction works and supports the digitalisation of the construction sector Supports use of prefabricated materials Enables better planning of materials needed – reduced risk of ordering more than needed	BIM requires software and skills, which comes with a cost	Can generate data and thus support the digital building logbook and smart readiness indicator Can integrate single-building planning into district-wide planning Can be used to show compliance with various certification schemes	Liability issues: who is the liable party when the BIM design has been developed by multiple actors (e.g. if the building doesn't comply with the building regulations)?

Policy action 5.3: *Enable public and private entities to aggregate demand for energy renovations, to facilitate higher production rate and industrialised renovation approaches*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: One significant barrier to accelerating building renovation is a small size and fragmented nature of projects, especially in the residential sector. Aggregating demand to facilitate large-scale renovation projects and achieve cost reductions by economies of scale is a way to realise larger renovation projects, which financial institutions are more likely to fund. The aggregation of renovation projects is also a prerequisite to creating a market for industrialised renovation approaches, e.g. with prefabricated building components and digital solutions.

Why: To benefit from industrial-scale production of (prefabricated) building components and digitalised design and planning processes, and cost reductions associated with this, demand has to be constantly high to reduce risks for the manufacturer and general contractors offering holistic renovation solutions. Especially for social housing companies/associations, aggregated projects and large-scale solutions have proven to provide lower costs and faster implementation of renovations.[100] Finally, increased digitalisation, automation and reorganisation of the construction process including the entire value chain mitigates the lack of qualified staff in the construction sector.

How: The EU could set up guidelines for the Member States to assist them with setting up programmes. Important considerations include:[101]

- Regional renovation platforms and one-stop-shops would help aggregate demand of local small and municipal housing companies.
- Standardised model contracts and blueprints for performance guarantees could reduce administrative costs and thus alleviate the hesitation of building owners and investors towards these kinds of projects.
- Public tenders should require a minimum project size.
- Setting performance guarantees could have a significant effect on the value chain, incentivising the construction sector to make better use of BIM, standardising collaboration with suppliers and thereby raising the overall quality of renovation services.

When: In line with the introduction of one-stop-shops and the 2021 EPBD revision.

Links with existing and other suggested actions:

- Energiesprong in the Netherlands, with replications in the UK, France and Germany, is the leading examples.
- Several Horizon 2020 and P7 projects have explored this concept, including BERTIM, ProGETonE and 4RinEU.

[100] See Energiesprong's experiences. (Available: Website).

[101] A report commissioned by the German Environmental Protection Agency UBA (Co2online & BPIE, forthcoming) has analysed existing experiences in Europe and includes a range of recommendations which also inform this section.

Impact consideration of Policy Action 5.3

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Industrialised renovation can accelerate deep renovations Alleviating lack of qualified staff for deep renovation since less labour is required Prefabricated approaches can reduce cost and time spent on site	Costs still higher than expected, thus competition with traditional renovation remains high	Incentivising innovation in the construction value chain, boosting the application of BIM, automation in production process and operation, display of real data addressing behaviour	The expected cost decrease doesn't materialise Aesthetics of the solutions not satisfactory

3.8. Cluster 6: Achieve policy integration through information exchange hubs and integrated urban planning

District approaches are crucial to achieving European objectives for a sustainable built environment including the decarbonisation and climate resilience of the building sector. A district or urban quarter is the centre of daily life and serves multiple purposes for the citizen: shelter and home, mobility, access to services, leisure activities and work. Understanding decarbonisation and climate resilience as a common undertaking at a district level will help to aggregate demand, make infrastructure investment more viable from an economic viewpoint and help to allocate trade-offs in the ambition level of individual renovations (e.g. in a case where heritage buildings will not be able to decrease their energy consumption level below NZEB threshold, this can be offset by positive-energy buildings and/or renewable heating supply). With improved and increasingly available data through digital building logbooks, priority areas can be identified and thus spur the phasing out of inefficient buildings. A joint effort is required at all levels, EU, national and local. The EU and its Member States could require municipalities to identify and support energy-poor and vulnerable groups with the help of urban planning. They could set up guidelines and forums for good practice exchange to assist municipalities in this effort.

In addition, the EU should initiate the setting up of regional renovation platforms that facilitate cooperation between municipalities and regions, finding solutions on an operational level and creating synergies for all strategic areas analysed in this study. While initiatives have already been launched at the EU level[102] and in the Member States, the benefits are clear and could be explored further. Such platforms could also serve to identify opportunities for circular approaches.[103]

The diversity of Europe's building stock requires tailor-made policy solutions which will lead to full decarbonisation of the sector. The multitude of innovative solutions developed at small scale, often in innovative cities and regions, offer a wealth of experiences which need to be shared with decision-makers across Europe, so that they can be replicated and scaled up. With increased exchange, learning will increase, which in turn will lead to inspiration, dissemination, scaling up and fine-tuning of policy approaches. Facilitating multi-stakeholder exchange and learning platforms to trigger innovation, collaboration and replication of good practices should be enhanced and expanded to new topics and arenas taking onboard stakeholders that may have traditionally not been part of the building sector exchange working, e.g. on the circular economy, digitalisation, energy systems, public health and sustainable mobility.

The actions proposed in this cluster aim at improving integrated municipal planning by requiring planning (action 6.2) and supporting it through exchange and capacity building activities (action 6.4). In addition, two aspects were singled out as a priority for local planning. First, supporting energy poor-groups to carry out building renovation (action 6.1) and promoting green infrastructure at the local level (action 6.3).

[102] See, for example, the regional collaboration work by Interreg. (Available: Website).
[103] For example, stocks of reusable local materials; locally based urban mining opportunities; hubs where such materials and products can be made available and put to use.

Figure 13: Policy actions in Cluster 6: Achieve policy integration through information exchange hubs and integrated urban planning

Policy action 6.1: *Guide and require municipalities to identify and support energy-poor groups*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Urban planning may help to identify priority districts to be upgraded and deeply renovated. Energy-poor households could benefit especially from this. Policies addressing energy poverty should improve the energy performance of buildings to benefit from long-term cost savings, and the related health and increased comfort benefits. The link between energy-poor, vulnerable groups and worst-performing buildings was also acknowledged in the Commission recommendation on energy poverty[104] published together with the Renovation Wave. Member States should be required to adopt an official definition of energy poverty in cooperation with social NGOs and associations that reflect the local circumstances of vulnerable groups and worst-performing buildings.[105] In addition, Member States should encourage municipalities to apply tools to identify the overlap of districts with households at risk of being energy-poor and worst-performing buildings.[106]

Why: Member States are required to identify the number of vulnerable households and implement measures to alleviate energy poverty in their LTRS; however, most countries have not adopted official definitions and established indicators that reflect the local building stock as well as climate and socio-economic situations. Social tariffs and energy bill support are widespread policies to tackle energy poverty but do not provide a long-term solution which is why an improvement of households' energy efficiency is crucial (e.g. free renovation works targeted for vulnerable groups).[107]

How: Energy poverty indicators should match available local data or identify missing data and be in line with local long-term decarbonisation strategies and urban planning activities. Low-interest loans or subsidies might miss the target when homeowners are not able to finance their own contribution. Member States should also be encouraged to make use of data mapping to show overlaps between energy poverty and worst-performing buildings, allowing for targeted (district) renovation approaches. EPC databases can already provide basic data. GIS, BIM and the digital building logbook provide more advanced options to identify and display the overlaps.

When: The EPBD revision should include a requirement to outline energy poverty definitions that acknowledge the local circumstances of the building stock and establish indicators reflecting available local data sources. The integration with cohesion and urban and regional development planning should be encouraged, for example through the targeted use of cohesion policy funds (e.g. for technical assistance).

[104] European Commission (2020) Recommendation on energy poverty. (Available: Online).
[105] Creutzfeldt, N., Gill, C., McPherson, R. et al. (2020) The social and local dimensions of governance of energy poverty: Adaptive responses to state remoteness. *Journal of Consumer Policy* 43, 635–658. (Available: Online)
[106] There are examples of geomapping already, see e.g. Färber, M. (2013) Energetische und Soziale Problemlagen in Berlin. Eine GIS-gestützte Untersuchung von energieeffizienter Wohngebäudesanierung im Hinblick auf sozioökonomisch schwache Gebiete. Graue Reihe des Instituts für Stadt- und Regionalplanung Heft 46 (Available: Online).
[107] Thomson, H. & Bouzarovski, S. (2018). Addressing energy poverty in the European Union: State of play and action (Available: Online).

Impact consideration of Policy Action 6.1

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Integrated cohesion and urban planning can create synergies at the municipal level	Lack of data (e.g. on cooling in summer, health and wellbeing impacts and household needs)	Strengthen the EU Energy Poverty Observatory platform with local data and policies	Difficulty of defining prioritisation criteria for energy-poor and vulnerable groups Lack of resources at local authority level

Policy action 6.2: *Require integrated municipal planning*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Municipal planning should be required to be integrative, including the development of an overall vision, setting concrete targets and indicators to measure implementation, implementing principles such as "energy efficiency first" or climate resilience, developing action plans and building an adequate multi-level governance structure.

Why: Planning is the main tool at the municipal level to initiate transition processes. If integrative and making use of digital tools, it can improve public health through strengthening active transport modes (e.g. walking and cycling), improve air quality (e.g. through clean mobility solutions), preserve cultural heritage, and integrate climate mitigation and adaptation measures.

How: Choice of 100 pilot projects in the framework of the Affordable Housing Initiative, as announced in the Renovation Wave, should meet certain criteria, including the use of digital building logbooks and the obligation to derive a blueprint for integrative municipal planning alongside project implementation touching on all seven strategic areas.

Subsequently, those blueprints should feed into guidance documents as an enabling framework, as well as criteria required in integrative municipal plans. The criteria in the municipal plans should meet and should go beyond the SECAP[108] requirements and they should be spelt out similarly to Article 2a of the EPBD for the national LTRS.

Funding opportunities are currently often focused on one strategic area (e.g. only bike lanes or only building renovations). If municipalities want to remodel whole districts (buildings, mobility, digital infrastructure, parks, etc.) they are not fit for purpose. A more flexible instrument, initiated by the EU or the Member States, could enable more holistic and integrated municipal planning.

When: In 2021 with the launch of the Affordable Housing Initiative, establish the requirement for integrative municipal planning from 2022 including milestones for renovation rate, decarbonisation of heating and cooling, implementation of digital building logbooks, clean mobility, climate resilience, and the reduction of energy poverty.[109]

Links with existing and other suggested actions:

Setting up integrative municipal plans should be developed either in one step with policy action 1c, or in strong collaboration and mutually referring to each other.

Also, digital building logbooks (policy action 3c) can be key instruments for better planning to identify priority areas and measure success.

[108] Sustainable Energy and Climate action Plans (SECAP) have to be provided signatories of the Covenant of Mayors for Climate and Energy

[109] This should also be inspired by the EU Commission's Mission Area: climate-neutral and smart cities (Available: Website).

Existing cases:

- Local planning tools, including sustainable urban mobility plans (SUMPs), are valuable instruments are already widely used.
- For sustainable mobility, the Netherlands and Denmark have gained ample experience of making urban transport more versatile and sustainable, which can be shared if resources and forums for this kind of exchange are available (see Action 6.4).

Impact consideration of Policy Action 6.2

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	W Weaknesses	O Opportunities	T Threats
Concrete indicators to measure success across Europe Enables municipalities to make future-proof investment decisions		Overcome silo approaches to planning Upgrade urban environment Fair distribution of benefits	Lack of capacity of especially smaller and poorer municipalities (consider exemption for municipalities <20,000 inhabitants and set up technical assistance) Lack of implementation (consider enforcement rules including conditional funding)

Policy action 6.3: Ensuring district-level application of green and blue infrastructure for new and renovated buildings and in public space

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Over the past decade, continuous biodiversity loss due to the degradation of natural ecosystems has negatively impacted the delivery of ecosystem services with direct effects on human wellbeing. The concept of green and blue infrastructure is "a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services."[110] Green infrastructure[111] should be integrated into spatial and urban planning more strategically to protect nature and acknowledge the link between biodiversity loss and climate change as reiterated by the EU 2030 Biodiversity Strategy.

In the context of the built environment, green infrastructure can be applied in the form of green spaces (e.g. parks, recreational areas) as well as green roofs or green walls to support resource efficiency and increase sustainable urban drainage. These forms of nature-based solutions are adapting the built environment to the effects of climate change, contributing to sustainable, climate-resilient buildings. Comprehensive district-level planning of long-term decarbonisation strategies offers the chance to integrate green infrastructure aspects into the planning of new built or renovation projects. With rising temperatures and increased precipitation, climate adaptation measures are becoming increasingly important in the EU. There is a need for climate-resilient buildings, natural and low-energy cooling measures and improved water retention (see the thematic area of 'Built environment sustainability and adaptation to climate change').

Why: Green infrastructure delivers ecological, economic and social benefits through natural solutions and thereby contributes to better resource efficiency, biodiversity protection, climate mitigation and adaptation as well as human physical and mental wellbeing. Regarding the built environment, green infrastructure measures can contribute to better-performing buildings. As mentioned, green roofs can reduce the energy required for heating and cooling and contribute to biodiversity in urban areas. Green infrastructure can also help combat urban heat island effects that occur in densely urbanised areas as grey infrastructure (buildings, roads and other built infrastructure) absorb and re-emit more heat than natural, green landscapes.

The recent EU 2030 Biodiversity Strategy[112] reiterates the importance of greening urban areas and announces the development of urban greening plans for cities of more than 20,000 inhabitants. These obligations should be interlinked with energy and building policies and urban planning frameworks to exploit the synergies towards sustainable, resource-efficient development and a decarbonised building stock.

District-level planning should exploit synergies between green infrastructure, climate mitigation and climate adaptation measures that simultaneously support the development of a sustainable built environment and alleviate biodiversity loss. Contrary to some technical adaptation solutions, nature-based solutions do not have direct negative side-effects due to higher energy use but support human health and wellbeing.

[110] EU Strategy on green infrastructure. [COM(2013) 249 final]. (Available: Online).
[111] The EU definition of green infrastructure includes aquatic ecosystems in its meaning.
[112] EU Biodiversity Strategy for 2030 – Bringing nature back into our lives. COM(2020) 380 final.

How: District-level plans could be harmonised with the ongoing work of the Covenant of Mayor's Sustainable Energy and Climate Action plans that integrate adaptation measures and the activities under the EU 2030 Biodiversity Strategy. EU requirements ought to build on but go beyond the work of the Covenant of Mayors. Based on existing good practices, the EU Adaptation Strategy should outline how green and blue infrastructure can be applied to buildings at a district level.

Municipalities should consider linking green infrastructure obligations to their public procurement policies when planning new districts and buildings. In line with Policy Action 1.1 and 1.3, Member States should be required to set holistic local long-term strategies covering decarbonisation targets and renovation plans including green infrastructure to ensure a climate-resilient building stock.

The EU should take a stronger guiding role and include green infrastructure in the EU Adaptation Strategy as well as suggest green infrastructure measures at the district level with the planned EPBD revision.

Existing cases:

- The Belgian municipality of Laarne plans to extend its green and blue network by developing green walls as connecting elements as part of its Covenant of Mayors Sustainable Energy and Climate Action Plan.[113]
- The Irish Dun Laoghaire Rathdown county is implementing a green roofs strategy on civic buildings as part of its Covenant of Mayors commitment (2019 SECAP).[114]
- Several German cities are financially supporting green roofs (e.g. Bremen, Stuttgart); Hamburg has a comprehensive strategy[115] with a target of green roofs on 70% of new buildings (~100 ha).
- The Brussels Sustainable Building Guide initiative offers guidance material for the development of ecological green cities, green roofs and walls. A pilot project is developing an indicator (CBS+)[116] to evaluate the ratio between urban areas favouring biodiversity and the total area under assessment.

When: EPBD revision, sustainable built environment strategy 2021

This action could be linked with Policy Action 1.3 and 6.2.

Impact consideration of Policy Action 6.3

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings		■			
CO_2 emission savings		■			
Increased renovation rate and depth		■			
Reduction of energy poverty		■			
Improvement of health and wellbeing				■	
Increased sustainable infrastructure				■	
Increased smart readiness	■				

[113] Covenant of Mayors for Climate & Energy, Laarne, SECAP 2020. (Available: Website)
[114] Covenant of Mayors for Climate & Energy, Dun Laoghaire Rathdown , SECAP 2019. (Available: Website).
[115] Green roof strategy Hamburg. (Available: Website).
[116] Guide bâtiment durable, Brussels. Favoriser la biodiversité. (Available in French: Online).

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Comprehensive urban planning at municipal and district level can save resources and create synergies Simultaneous human health and wellbeing effects		Accelerated implementation of the EU Biodiversity and Green Infrastructure Strategy Synergies with the alleviation of biodiversity loss	Contradictory targets of climate mitigation and climate adaptation measures (e.g. dense building structure to prevent heat loss vs. increased green spaces between buildings)

Policy action 6.4: *Support regional exchange platforms to trigger innovations, collaboration and replication of good practices*

Sustainable mobility	Digital technology	District approaches	Engaging transformation	Financing renovation	Built env. sustainability	Health and wellbeing

What: Policy innovation is expected to play a crucial role in the transition towards a decarbonised building stock. Innovative policies can be either small and incremental or large and radical, but what unites them is that they involve the realisation of new ideas, processes and practices that break with the past.[117]

This action suggests that the EU support Member States and regions to set up regional exchange platforms to facilitate replication of good practices, the spread of innovation, training collaborations and other synergies. The platform can comprise workshops, training of experts, good practice exchange dialogues and many other interactive learning and exchange approaches. It should also be dedicated to topics formerly less prominent in the building sector, expanding into the wider built environment, e.g. clean mobility with a focus on cycling infrastructure.

Why: As this study shows, several countries and local authorities have introduced innovative policies and programmes to stimulate deep renovation and reduce the CO_2 emissions of the building sector. However, broad dissemination and application of these policies are not taking place. The exchange of information and experiences across regions is much lower than would be desirable.

How: Expand the scope of ELENA to provide technical assistance for regional exchange platforms. A blueprint for the key elements of such a platform should be provided (including the provision of training programmes on project implementation, upscaling and dissemination as well as an exchange platform), making clear, however, that it needs to be adapted to regional circumstances.

When: In the next year(s) to support the introduction of the Renovation Wave.

Links with existing and other suggested actions:

- The Swedish cities of Malmö and Borås have developed "innovation platforms", with the aim to foster collaboration around a more sustainable building stock. The concept of innovation platforms implies formalised cooperation between actors (businesses, public organisations, research institutes, universities etc.) involved in research and innovation.
- The Living Lab Housing Renovation programme in Flanders is fostering innovation through cross-governmental dialogue. Multiple actors are involved in the dialogue, including ministries and administrations of innovation, energy, (social) housing and financing, and local authorities. The main objective is to initiate innovative, scalable and replicable renovation concepts that make deep renovation affordable.
- The European Climate Protection Initiative of the German Environmental Ministry (EUKI) is providing not only grants but all kinds of support to their grantees, including an academy programme with specific training according to particular needs and a platform to exchange information on the projects. The aim is to help grantees implement their projects but also find ways to scale them up and disseminate ideas more widely.

[117] BPIE (2018) Policy innovation for building renovation. Climate-KIC. (Available: Online).

Impact consideration of Policy Action 6.4

Impact indicators	N/a	Minor	Average	Good	Excellent
Primary energy savings					
CO_2 emission savings					
Increased renovation rate and depth					
Reduction of energy poverty					
Improvement of health and wellbeing					
Increased sustainable infrastructure					
Increased smart readiness					

S Strengths	**W** Weaknesses	**O** Opportunities	**T** Threats
Capacity in local authorities is a key enabler of innovative policies Building a strong network with local actors will increase trust in the process	Many platforms and forums already exist	Strong city commitment and clear targets (e.g. GHG emissions, climate resilience) tend to trigger innovation Collaboration between different stakeholders is very important in the building sector as currently there is no exchange of information Need to hear the views of people working on the ground Many platforms and forums already exist, which can be built upon	Language is a crucial aspect of widespread replication and scaling up of innovative renovation policies, which can hamper cross-border collaborations

4. CONCLUSIONS: OVERALL LESSONS LEARNED

European Member States have implemented a wide variety of policy instruments addressing the key EU challenges of the seven strategic areas analysed in this study. However, the efforts are neither sufficient nor coordinated across strategic areas. While a lot of European legislation and incentives have been put in place, the implementation at the national and sub-national level is insufficient. The recently submitted long-term renovation strategies of the Member States, as well as the fact that not all Member States have handed in their LTRS more than half a year after the deadline, are evidence of this. At the same time, there are a lot of promising research activities across Europe. While it was not within the scope of this study to screen ongoing research activities, it became clear throughout the study that a lot of research and demonstration activities are still far from reaching the mass markets and lack support from national and local policymaking to be widely adopted.

It is unrealistic to expect that policies and actions at the EU level alone can address all remaining problems adequately. All measures need to be implemented at the national and sub-national level – including by regions, districts, municipalities and, by extension, building owners. Cities are important levels of aggregation of demand, which has a direct impact on scale, risk and economies of scale. Action and support are needed from a variety of actors, including the construction industry, suppliers, energy advisors, financing institutions and social housing companies. Still, the European policy framework has been an important driver for policy implementation in the Member States.

Several policy instruments are best placed at the European level to increase learnings and synergies among the Member States (e.g. when setting up building renovation passports), to ensure a level playing field (e.g. carbon tax) and to secure comparability between the Member States via harmonised approaches e.g. concerning data collection and accessibility (e.g. in the context of EPCs, digital building logbooks, methodologies to calculate the embedded carbon of buildings). The European level is also best positioned to steer good practice exchange (e.g. on climate adaptation measures and sustainable mobility, but also regarding innovative financing tools and lighthouse projects to alleviate energy poverty and implement future-proof districts). Finally, technical assistance on all aspects can be incentivised and informed by European policymaking and is thus crucial to achieve a decarbonised building stock and a sustainable built environment across Europe.

A series of lessons with cross-area relevance have been drawn from the analysis. Together with an analysis of good practices from all over Europe and more specific lessons per strategic area, they have informed the drafting of policy actions in the last part of the study.

Lesson learned 1: *Regulation and mandatory requirements are an indispensable part of the policy mix in most strategic areas*

Regulatory requirements are among the most promising policy instruments to effectively address the split-incentive dilemma – one major barrier towards deeper and faster energy renovation. However, different kinds of regulatory instruments and mandatory requirements are in place and they vary in their level of application. Also, minimum requirements for data collection, e.g., via energy performance certificates (EPCs), for urban planning, or for sustainable building design are impactful instruments and a precondition to set a more ambitious baseline for action at the Member State level.

Lesson learned 2: *Mandatory minimum energy performance standards (MEPS) play an important role in driving building renovation*

One specific part of this study (Annex IV) explores mandatory minimum energy performance requirements for existing buildings (here referred to as MEPS). MEPS are a regulatory requirement mandating buildings to meet a defined performance threshold, by a specified compliance date or according to natural trigger points in the building's lifecycle (e.g. time of sale). MEPS can apply to all buildings or particular building segments.

MEPS have already been implemented in various jurisdictions for this purpose, especially across Europe and the United States. For example, the UK, France, the Netherlands, and Belgium (Flanders and Brussels) have implemented, or have far-reaching plans to implement, MEPS for existing buildings. The common purposes of these regulations are to phase out the worst-performing buildings through renovations and to reduce energy poverty.

Annex IV presents a range of policy pathways outlining how MEPS can be supported and enforced by the EU. They have the potential to drive renovations when implemented effectively and with clear timelines. A progressively tightened requirement could help operationalise the objective of a highly efficient and decarbonised building stock by 2050.

Lesson learned 3: *There is further need for effective use of trigger points to enact deep energy renovation*

Trigger points are key moments in the life of a building (e.g. rental, sale, change of use, extension, repair or maintenance work) when carrying out energy renovations would be less disruptive and more economically advantageous than in other moments. Available funds often reach recipients who have a well-developed project in place. While the Energy Performance of Buildings Directive (EPBD) already emphasises the importance of trigger points to activate renovation beyond business-as-usual, country research shows that there is still room for strengthening the use of trigger points and to think of new points to trigger deep renovation. One example would be to define trigger points in improving accessibility for people with disabilities. Work to upgrade a building to comply with accessibility provisions could serve as trigger points to assess and possibly deploy deep renovation options and vice versa.

Lesson learned 4: *A general lack of data must be addressed*

The lack of accessible and reliable data is a persisting challenge across all strategic areas. Existing databases, such as building registries and cadastres, EPC databases, material passports and the European Building Stock Observatory, differ in collection methodology, data specification and thus comparability, comprehensiveness, and accessibility. Besides the diversity of approaches, data protection concerns are inhibiting improvements in data collection. Better and more comprehensive data is needed to understand the energy performance and the overall condition of the EU building stock. This includes comprehensive and accessible data derived from EPCs, data on real-time energy consumption and according to monitoring and display, the share of renewable energy, carbon emissions, the lifecycle carbon impact of buildings, additional benefits and the smart-readiness of the building. The private sector is the key enabler in this effort, as it already produces and gathers a large amount of building data. Also, data collection at the local level should be encouraged by providing financial support, technical assistance and capacity building to municipalities and supporting citizen science projects.

***Lesson learned 5**: Digital building logbooks can help fill the data gap*

A policy instrument that has gained cross-sectoral attention is the digital building logbook, which is a common repository for all building related data. For each strategic area, it serves slightly different purposes. Doing so, it can be a way of integrating different policy areas, by e.g. increasing the lifecycle perspective for new and existing buildings, informing planning by collecting and mapping data to better identify priority areas/districts for aggregated renovation projects, integrating mobility planning, integrating administrative information such as permits and requirements for compliance, or possibly including information on IEQ. Digital building logbooks can make sure experts have all possible information before visiting the building, which will optimise the required time on-site and thus also the related cost. Related to this, energy experts ought to be trained to have a more holistic understanding of the building compared to the performance of separate building elements and its interaction with the district and wider energy systems.

***Lesson learned 6:** Strengthening energy performance certificates could create multiple benefits*

In implementing the EPBD, EU Member States have established national EPC schemes. Improved and better-aligned EPCs could be beneficial to many strategic areas. They could include information on the carbon performance and provide information on renovation costs and thereby help to better capture trigger points. They could also be a dynamic data repository once digitalised, online and accessible, and prove compliance with policies (e.g. with mandatory minimum performance requirements; proof of eligibility for financial support, etc.).

***Lesson learned 7:** Urban planning is a promising way towards policy integration*

Urban planning is the obvious choice for the integration of different strategic areas (buildings, heating/electricity systems, sustainable mobility etc.). Planning takes place at different scales and should be used, among others, to prevent urban sprawl, operationalise aggregated renovation projects and integrate infrastructure for sustainable mobility. To unfold the planning potential, the EU should recommend the specification of minimum requirements in existing urban planning, e.g. for mobility plans to the extent possible through existing directives (e.g. Strategic Environmental Assessment (SEA) Directive[118]), or require the Member States to report on how they take certain aspects into account in their national and subnational planning tools. New planning principles such as the 15-minute city, the energy efficiency first principle and re-densification should systematically be implemented.

***Lesson learned 8:** New approaches need to become better known across sectors*

The country research revealed that while some policy concepts are well known at the European level and among scientific and academic stakeholders, many policy concepts need further explication and dissemination both vertically to national and subnational governance levels and across the sector. Among those are new ways of financing, such as on-bill or on-tax financing, project aggregation and renovation services that offer solutions via one-stop-shops, definition and meaning of nature-based solutions, a clear definition of a district approach, or benefits of deep energy renovation for health and well-being and on the importance of IEQ.

[118] Directive 2001/42/EC of the European Parliament and of the Council of 27 June 2001 on the assessment of the effects of certain plans and programmes on the environment (Available: Online)

Lesson learned 9: *Financing remains a bottleneck for implementing a decarbonised and sustainable built environment*

Financing has been identified as a bottleneck in many strategic areas examined in this study. Innovative financing instruments need to become more widely deployed, which requires promotion campaigns, collaboration with local banks as well as innovation support for SMEs. In addition, new business models are required to facilitate the Renovation Wave, such as aggregation of renovation projects, industrialisation of renovation processes e.g. through the use of prefabricated systems for deep renovations, and the use of robotics and automatisation to optimise the process. Multiple opportunities for the construction value chain will arise, driving marginal improvement as well as larger disruptive innovations. Long-term financial support mechanisms, public and private, are needed to kick off the transformation and to ensure companies make the long-term capital investments (such as a factory to facilitate large production of prefabricated facades or HVAC).

Lesson learned 10: *Available digital technology should be rolled out to enable promising approaches to support the creation of a sustainable built environment*

Digital technology development is advanced e.g. in reaping flexibility gains from the demand side, but it is not yet fully exploited for the creation of a sustainable built environment. For example, while BIM is ready to be used in constructing new buildings, it is not yet mainstream in most markets, only a few solutions exist for the renovation of existing buildings and the cost for BIM remains a barrier in some markets. New opportunities to utilise digital innovations to decarbonise the existing building stock are still not fully explored, due to path-dependency or the remaining profitability of traditional practices. Better data collection and the use of digital solutions (e.g. making use of blockchain technology, digital building logbooks, or at least improved and web-accessible EPC databases) can steer the reorganisation and optimisation of construction and renovation processes.

Lesson learned 11: *Transparent communication and stakeholder interaction and engagement are critical success factors*

Across all strategic areas, transparent communication and stakeholder interaction and engagement help to build mutual trust and are key to enforce viable policy and technical solutions. This is especially relevant for urban planning but not restricted to this. There are several ways the EU is already promoting participatory approaches and communication. Besides supporting exchange and engagement by requiring participation processes, setting out guidelines or supporting networking, good practice exchange demonstrating the multiple benefits of building renovation could be an important driver.

Lesson learned 12: *Mobilisation of market-based approaches has been limited in existing policy mixes to date*

While there are examples of market-based approaches for building renovation and for the wider built environment, such as CO_2 price, the planned extension of the emissions trading system (ETS) to buildings and road transport, secondary material quotas, aggregate levies, or energy saving obligation schemes, they currently do not play a major role in decarbonising the building stock. This may be due to the still-moderate targets and price levels found in existing cases (also driven by social acceptance constraints), although some instruments have delivered energy savings and greenhouse gas (GHG) emission reductions. Another plausible reason is that many of the barriers to renovation are non-economic barriers and can thus not be fixed with market-based approaches solely.

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6. APPENDIX: INITIAL LIST OF POLICY ACTIONS

The good practice examples of the strategic area factsheets (Annex II) have been further analysed (Annex III, Annex IV). Based on this, a pre-selection of policy action has been derived. The good practices have been initially clustered according to types of policy instruments to make sure that the selected policy actions consist of a mix of policy instruments and cover all strategic areas.

Mandatory policy instruments/regulation

1. Facilitate and encourage the introduction of next-generation building regulations, by:

    1a) Integrating whole lifecycle carbon assessment, to make sure the overall carbon footprint is minimised

    1b) Integrating indoor environmental quality to maximise the multiple benefits related to better buildings

    1c) Exploring how to include parameters regarding users' energy consumption behaviour, to mitigate the impact on the "performance gap"

    1d) Integrating adaptation/resilience requirements, in particular for building segments, especially in vulnerable districts (risk of seismic activity, flooding, extreme heat/cold etc.)

    1e) Integrating accessibility as a trigger point for energy renovation, and vice versa

    1f) Exploring how to integrate renovation obligations for existing buildings, beyond "major renovation" standards.

2. Introduce requirements to use building information modelling for larger new buildings and public infrastructure projects.

3. Introduce a mandatory digital building logbook for new and public buildings throughout Europe.

4. Introduce legal requirements to incentivise sustainability in the construction and building sectors, including climate resilience.

    4a. Define the standard for future-proof buildings, assuring the owner that the building is 2050-compliant (e.g. net-zero carbon building) and climate-resilient

    4b. Require in public procurement a quota of reused, repurposed or upcycled components.

5. Introduce mandatory minimum requirements for existing buildings based on progressive minimum energy efficiency requirements.

6. Strengthen requirements to enable demand-side flexibility in buildings, including electric vehicle charging stations, demand response and automation.

7. Introduce rights for tenants to request renovation, if the dwelling doesn't meet certain standards (local/regional).

8. Introduce a requirement for building renovation passports for all buildings and create links with district plans.

9. Review the public procurement rules to better value high-performing, low-carbon and climate-resilient solutions.

Strategies and planning

10. Mandate local long-term decarbonisation strategies, including mobility, digitalisation, sustainability, adaptation and financing.

11. Require plans to minimise the whole-life carbon impact of building renovation in the long-term renovation strategies.

12. Encourage national policy requiring fossil-fuel-free district plans.

13. Enable public and private entities to aggregate demand for energy renovations, to facilitate higher production rate/industrialised renovation approaches.

14. Increase the requirements for the Member States to assess the vulnerability of their building stock to the adverse effects of climate change

Marked-based instruments and financial support

15. Introduce a levy on certain building materials, including concrete, steel and various materials.

16. Integrate real-time energy savings data into required information collected on a building, and encourage differentiated (grid) tariffs for buildings.

17. Introduction of a carbon tax/price.

18. Address market fragmentation and barriers hampering the deployment of energy efficiency mortgages.

19. Encourage Member States to dedicate financial support for adaptation/resilience measures for vulnerable building segments (risk of flooding, fires, and other extreme weather conditions).

20. Increase municipal capacity across the EU to utilise existing and new financial mechanisms.

21. Set up special grants for positive carbon districts and neighbourhoods.

22. Enhance the deployment of energy performance contracting.

23. Guide and require municipalities to identify and support energy-poor and vulnerable groups, enabling a shift from energy subsidies to renovation support.

24. Provide public support or grants for ambitious levels of verifiable energy improvements and savings, which could be easily coupled to green mortgage eligibility criteria (considering the full lifecycle) in terms of a single, streamlined application and approval process.

25. Broaden the cost-optimal definition, to incorporate all benefits.

Information

26. Support integrated renovation services, to create a smooth renovation journey for private citizens and municipalities.

27. Analyse where adaptation actions are most important, and identify what measures are needed.

28. Encourage Member States to make building-related data available and attainable, such as in a digital building logbook.

Voluntary instruments

29. Create voluntary reporting frameworks

30. Support harmonisation/transparency of private certification schemes, such as BREEAM, LEED and DGNB (there is a current process of major European schemes aligning themselves with Level(s)).

31. Support multi-stakeholder exchange platforms to trigger innovations and collaboration.

32. Provide guidelines and good practice examples for local clean mobility solutions.

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