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INDUSTRIALIZED DEEP RENOVATION FOR SOCIAL HOUSING

a contextualized overview of Energiesprong retrofit model across Europe

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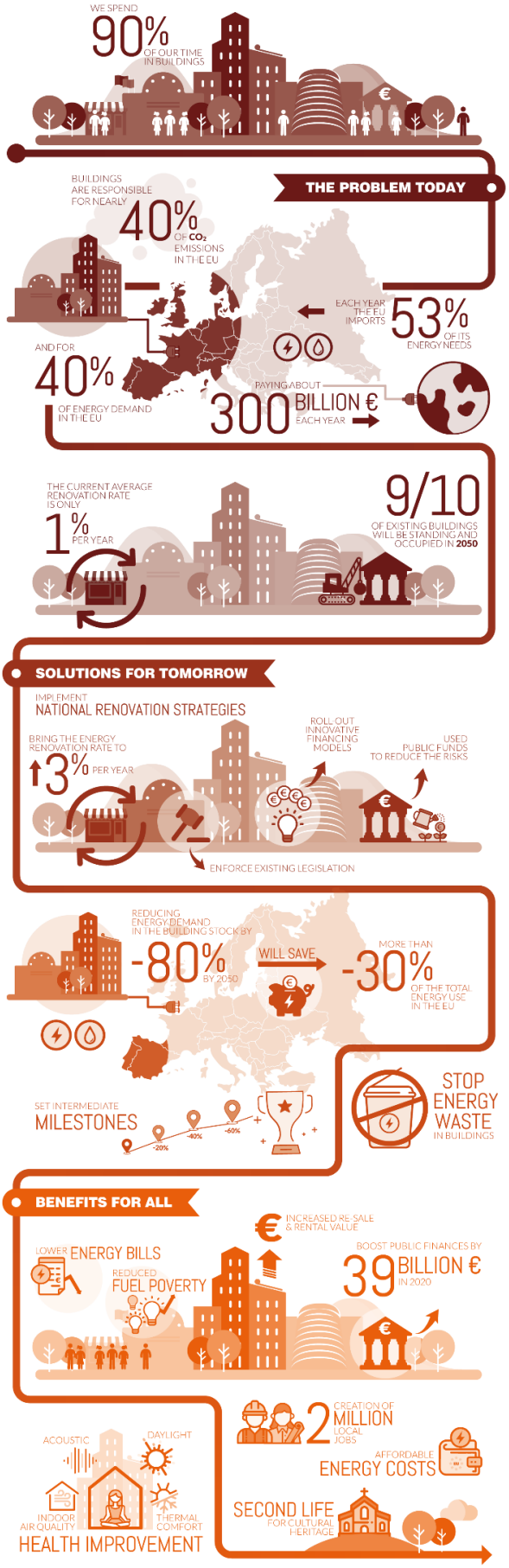
"Sustainability involves the simultaneous pursuit of economic prosperity, environmental quality, and social equity. Sustainable construction needs to perform not against a single, financial bottom line but against this triple bottom line" AND SO DOES BUILDING RENOVATION.

World Building Council



Source: Renovate Europe infographic "REDUCING THE ENERGY DEMAND OF THE EU BUILDING STOCK BY 80% BY 2050"

ABSTRACT

The thesis aims to analyse the most known industrialized deep renovation approach, called Energiesprong (meaning “energy leap” in Dutch). More in details, the work tackles its general business model and the current diffusion in The Netherlands, France, United Kingdom, Germany and Italy. Even tough every Country has its own peculiarities, they all have a common denominator: targeting the social housing stock with an innovative approach that has already renovated more than 7000 houses.

The ambition of the Energiesprong initiative lies in the urgent need for an effective energy transition, addressing both CO_2 emissions reduction and energy poverty fight. Indeed, while the European Union aspires to become the first climate-neutral continent by 2050, residential buildings still account for 30% of all energy consumptions and lead around 40 million households to experience inadequate levels of essential energy services, due to high bills cost. Change is slowly happening as evidenced by the over € 100 billion the European Union has allocated between 2021-2027 for buildings energy efficiency and the hundreds H2020, Horizon Europe, Life and Interreg projects funded by the EU to find innovative solutions and approaches to renovation.

In this field, social housing offers unique opportunities to tackle both energy efficiency and social inclusion by undergoing massive interventions able to activate economies of scale. However, a series of technical, financial and legal barriers make it resistant to change. This thesis shows how Energiesprong is trying to exploit the advantages of offsite solutions to implement high-quality, fast, affordable and attractive retrofits. Still, the road ahead is long: to reach the Renovation Wave goal of decreasing buildings GHG emissions by 60% (with respect to 2015 levels) before 2030, industrialized deep renovation models, such as Energiesprong, should spread in all EU countries to target the worst performing residential stock, estimated at some 40 million buildings across the continent.

Keywords: *Energiesprong; renovation wave; energy transition; industrialized deep renovation; offsite construction; social housing*

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INTRODUCTION

In the context of increasing ambitious climate targets to reach carbon neutrality by 2050, the 2020 **EU renovation Wave** placed particular emphasis on buildings as one on the most energy-consuming sectors, with the residential stock being the most impacting portion. The strategy demands for **at least doubling renovation rates in Europe**, focusing on deep and resource-efficient interventions. The two years that followed have been, then, marked by many unexpected changes and disruptions (from the impact of the pandemic to the energy crisis), exacerbating long-standing problems with affordability and cost of living. If, on one hand, housing owners and providers are asked for significant efforts towards energy efficiency, on the other, the boundaries conditions are less than ever favourable. To exit the current deadlock, forces must be joined in the direction of **innovative technical, legal, financial, and social solutions for a fair energy transition**. Among the others, one initiative was ahead of its time: it's called **Energiesprong** (energy leap, in Dutch), a revolutionary approach to whole house renovation, born in the Netherlands in 2010 and currently spread in France, United Kingdom, Germany and Italy. Its strength lies in its business model having a clear value proposition: using offsite retrofit components to create warmer and more desirable places to live that are financed by energy and maintenance savings and primarily target **social housing stocks**. The latter, indeed, offers a unique opportunity to deliver effective energy efficiency at scale, while being a key area of intervention of housing policies since it caters for low-income and vulnerable tenants, who are the most affected by energy poverty.

In this respect, the present research work aims at providing an **exhaustive and updated overview of industrialized deep renovation for the residential sector, with a particular focus on Energiesprong and the social housing stock.**

What are future EU emission targets and available resources? how is the current situation in terms of achievements and challenges? How can offsite integrated retrofits fill the gap and provide significant benefits? Is there a market initiative that has already taken hold and can returns the first empirical results?

These are just the main questions that each of the four chapters tries to answer to. Indeed, given the relevance and urgency of the theme, there is a proliferation of uncomplete and misleading information that prevent the reader from a clear and mindful understanding of both the need and the potential of innovative renovation schemes. Effort has, also, been dedicated to collect and standardize data, given that availability and quality vary significantly across time, countries, and topics. In addition, a reasoned systematization has been repeatedly needed to overcome the vagueness of terminology and definitions.

The **main beneficiaries** of the thesis are, then, citizens, housing providers and especially researchers or real estate consultants, with no prior knowledge of the topic, who are interested in a first taste and a reality check on the status of industrialized deep renovations. Many references can, indeed, be a valid starting point for more critical country-specific analysis and case studies.

More in detail, **Chapter One** traces the main goals, targets and policies the European Union has set from the 2015 Paris Agreement to date. The most relevant and analysed one are the 2020 Renovation Wave Strategy and the Energy Performance Building Directive, with all its amendments. Equally important is the description of all the funds assigned by the European Green Deal Investment Plan for the energy efficiency of buildings, mainly through the Multiannual Financial Framework and Recovery and Resilience Facility.

In **Chapter Two**, the overall European housing energy consumptions and emissions are reported to understand the current situation and the future efforts required to reach the 2030 and 2050 goals. Furthermore, high building energy needs imply unbearable utility bills that are responsible of the increasing energy poverty. Such phenomenon is, thus, described and quantified, leading the way to the characterization

of social housing, being the portion of the stock that offers the most interesting opportunities to address both energy efficiency and social inclusion.

Once objectives and challenges have been presented, **Chapter Three** introduces Industrialized Deep Renovation as a possible response to an urgent energy transition of housing. Beside the focus on its blurry definition, attention is given to the creation of an exhaustive taxonomy of all possible interlinked benefits brought by such approach with respect to traditional retrofit interventions. In addition, a list of properly filtered H2020, Horizon Europe, Life and Interreg EU projects tackling the topic have been provided as source of further insights.

To conclude, **Chapter Four** leaves the space to Energiesprong, as the most successful and diffused industrial prefabrication model for deep renovation projects to date. It is described in its general business model, highlighting the points of strengths common to all Countries: the involvement of market development teams; the economic feasibility given by the energy plan; the need of outcome-based procurement and the performance monitoring matched with a proper tenant engagement. Finally, the thesis ends up with an overview of Energiesprong implementation in The Netherlands, France, United Kingdom, Germany and Italy, contextualized by a brief analysis of their respective social housing models and financing schemes.

CHAPTER ONE
The European regulatory framework addressing building renovation

Worldwide the building construction industry accounts for the largest share of final energy consumption and energy-related CO_2 emissions (see ***Appendix A*** for energy flows definitions). According to the 2021 Global Status Report for Building and Construction (United Nations Environment Programme, 2021) adapted from the Tracking Buildings 2021 report (IEA, 2021) in 2020 the **construction sector was responsible for the 36% of total energy demand,** which is approximately 149 EJ (or about 3560 Mtoe) spread as follow:

22% for operational consumption of residential buildings (93 EJ)

8% for operational consumption of non-residential buildings (34 EJ)

6% for manufacturing building construction materials (22 EJ)

The remaining 64% is mainly consumed by other industries (32%) and transportation (26%), with the construction sector being the most energy-demanding one. A similar trend can be observed also in the EU region and in most of its countries, including Italy, as detailed in the following paragraphs.

Such a high energy consumption causes both social and environmental problems. In fact, energy-intensive buildings lead to high electricity and gas bills which are at the roof of the energy poverty condition of more and more households. Furthermore, in 2020, the **building construction industry accounted for the 37% of energy-related emissions**, equal to 12,3 $GtCO_2$ (IEA, 2021; United Nations Environment Programme, 2021), distributed as follow:

- **9%** (6% residential and 3% non-residential) of **operational direct emissions** coming from the combustion of fossil fuels produced in buildings, totalizing 2,9 $GtCO_2$;
- **18%** (11% residential and 7% non-residential) of **operational indirect emissions** coming from the generation of electricity and heat used in buildings but produced elsewhere, totalizing 5,8 $GtCO_2$;
- **10%** of **other emissions related to the manufacturing of construction materials** for new construction and renovation, totalizing 3.2 $GtCO_2$.

Compared to 2015, CO2 emissions had fallen of around 10%, after they peaked in recent years. This decline is largely driven by the reduced energy demand related to the COVID-19 pandemic. Indeed, even if efforts in decarbonizing the power sector are visible worldwide, a negative rebound of 5% have been experience in 2021, being 2% higher than the previous 2019 peak (United Nations Environment Programme, 2022).

Moving to the European Union, in the recent years, it **covered around the 10% (1000 Mtoe) of the world total final consumption** getting the fourth place after the United States, China, and the rest of Asia. The related EU CO_2 emissions, compared to the global ones, followed the same trend, being around the 8% of the total share (European Commission DG Energy, 2021).

In 2020 the **EU final energy consumption reached 886 Mtoe**, decreasing by 5,6% compared to 2019 and by 10,5% from its 2006 peak level. On the contrary, the **share deployed by households rose to 28%** due to the reduction in transport consumptions given by the Covid 19 pandemic (Eurostat, 2022c). It is worth mentioning that the household values include only the direct and indirect consumes of residential buildings

during their operational lifespan. It doesn't take into account non-residential buildings (considered within the commercial and public services) and the manufacturing of building construction materials (considered within industry), so it has to be compared with the 22% global residential average, since an aggregated EU value for the whole building construction sector is not available and it's beyond the scope of this thesis.

Due to such high levels of consumptions and emissions, many are the declarations of intent which show the effort that the world, the European Union, and single countries are involving in setting clear and increasingly stringent targets and regulations, as summarized in paragraph 1.1. To lay the foundations for a global commitment, during the COP 21 hold in Paris on 12 December 2015, the first legally binding international treaty on climate change, called **The Paris Agreement** (United Nations Framework Convention on Climate Change UNFCCC, 2016), was adopted by the European Union, together with other 195 parties. To reach its objective of keeping the global temperature increase to 1.5°C and below 2°C, the signing Parties had to submit comprehensive national climate action plans (called National Determined Contributions NDCs).

Since 2015, the number of countries mentioning actions to tackle buildings-related emissions in their NDC increased from 90 to 136. Also building energy codes (regulatory instruments that specify minimum energy efficiency standards for the residential and commercial stocks) raised from 60 to 80 and investments in energy efficiency continued to climb (+40%), mainly coming from a small number of European countries. However, the challenges are still considerable since, if the effect of the pandemic is excluded, the decarbonization level reached in 2020 is only the 40% of the reference value needed to achieve the Paris Agreement goals (United Nations Environment Programme, 2021). A triple strategy must be adopted to drastically lower buildings emissions: **reducing energy demand** (through energy efficiency measures and behavioural changes), **decarbonizing the power supply** (through electrification and use of renewable sources) and **addressing embodied carbon** stored in building materials (thorough the use of low-carbon solutions). In this direction, maximizing the refurbishment of existing buildings using a sustainable and whole life-cycle approach should be a key objective of upcoming policies and incentives.

1.1 EU climate goals leading to the Renovation wave strategy

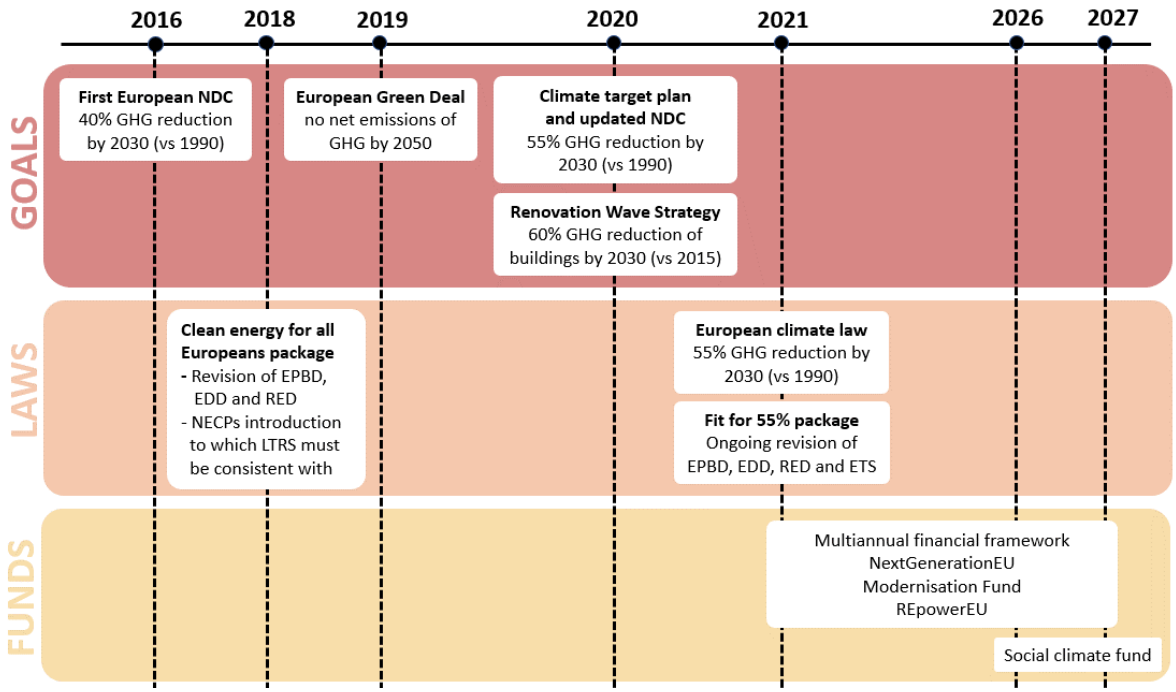


Figure 1 *Scheme summarizing recent EU goals, laws and funds targeting energy efficiency*

As a consequence of the increasing environmental crisis, climate neutrality is one of the most relevant and challenging goals of the whole European Union and, by extension, of its member states: reaching an economy with net-zero[1] greenhouse gas emissions by 2050 is at the heart of the European Green Deal (replacing the 80-95% emissions reduction target stated in the 2011 EU Communication entitled "Roadmap to a low carbon economy"), in line with the EU's commitment to action expressed in the Paris Agreement. In this field, several goals, laws and funds have been issued by the European Union as chronologically summarised in **Figure 1.**

On October 2016, the first European NDC expressed the intention to:

- reduce greenhouse gas emissions by at least 40% by 2030, compared to 1990 levels;
- reach at least 27% primary and/or final energy savings (see ***Appendix A*** for energy flows definitions);
- achieve a minimum 27% share of renewable energy consumption.

In December 2020 the updated NDC version enhanced the GHG emission target to **55%** without contribution from international credits, in line with the evolution of the EU's internal strategies as stated in the **Climate Target Plan 2030** (issued in September 2020) and written into the **European Climate Law** (published in June 2021) to deliver on the commitment made in the European Green Deal.

Indeed, **the European Green Deal** (European Commission COM(2019)640, 2019) presented by the Commission in December 2019, set the goal of making Europe the first climate-neutral continent within the 2050, by transforming the EU's economy for a sustainable future through 8 lines of action:

- Increasing the Eu's climate ambition for 2030 and 2050
- Supplying clean, affordable and secure energy
- Mobilizing industry for a clean and circular economy
- **Building and renovation in an energy and resource efficient way**
- Having a zero-pollution ambition for a toxic-free environment
- Preserving and restoring ecosystems and biodiversity
- Going from "Farm to Fork": a fair, healthy, and environmentally friendly system
- Accelerating the shift to sustainable and smart mobility.

Specific attention is clearly given to the construction sector to address both the challenges of energy efficiency and affordability, as described in the next paragraphs. In this regard, the Commission states the explicit need for a "renovation wave" of public and private buildings, boosted from the enforcement of the legislation related to the energy performance of buildings.

In line with this aim, in October 2020, the Commission presented its **Renovation Wave strategy** (European Commission COM(2020) 662 final, 2020a), as part of the European Green Deal. It contains a 2030 action plan with concrete regulatory, financing and enabling measures to boost deep renovation. More in details it sets specific goals with respect to 2015 levels, for the building sector to achieve the 55% target:

- decreasing greenhouse gas emission by 60%,
- lowering the final energy consumption by 14%
- reducing energy consumption for heating and cooling by 18%.

Overall, **the need is to at least double the annual energy renovation rate of all buildings resulting in around 35 million units renovated by 2030**. The strategy to be adopted follows seven key principles (energy efficiency; affordability; decarbonisation and integration of renewables; life-cycle circularity; health, safety, and environmental standards; green and digital transition; architectural quality) and it tackles the key

[1] Net-zero refers to the balance between the amount of greenhouse gas (GHG) that is produced and the amount that's removed from the atmosphere. It can be achieved through a combination of emission reduction (energy efficiency, e-mobility, etc.) and emission removal (reforestation, air capture, etc.).

barriers, at every point of the value chain, proposing a list of lead actions to enable the diffusion at large scale of deep renovations:

1. *Strengthening information, legal certainty, and incentives for public and private renovations*

Today the lack of information on current building energy profiles and potential energy savings generates mistrust in the benefits of renovation. Proposing mandatory minimum energy performance standards (combined with reliable energy performance certificates - EPC and linked to specific national, regional and local incentives) will provide a set of clear lines for decision-making and investments, raising awareness on renovation and on the value that improved energy conditions can add to the building.

2. Ensuring reinforced, accessible, and well-targeted funding

In the residential sector, the lack of easily accessible public incentives and the lack of mainstream financing products are often mentioned as one of the main barriers for building renovation, sector which is facing the largest investment gap in the EU to meet the 2030 targets. It is necessary to act both to increase the share of private funds and to foster a better use of public funds, making the intensity of support proportional to energetic and technical performances.

3. Increasing project capacity and technical assistance

The design of a good renovation project exploiting the most suitable financing sources is often very complicated for small local authorities, homeowners and SMEs. Thus, technical assistance reaching a larger pool of beneficiaries is crucial to increase the retrofit rate, depth and quality. In addition, standardised one-stop shops will be set up and deployed at national, regional or local levels to accompany needy entities throughout the implementation of their projects.

4. Creating green jobs, upskilling workers and attracting new talents

The design and installation of innovative and sustainable retrofit solutions usually require a high level of technical knowledge and specific skills. The transition towards a climate-neutral built environment will only be possible if new specialist job profiles (increasing the presence of women) emerge, who need to be well trained and informed on the latest technical opportunities for building energy efficiency, which is the sector with the largest generator of jobs per million euros invested. Parallelly, safety and health in construction must be addressed as well with a particular attention to protecting workers renovating old buildings through appropriate training.

5. *Making the construction ecosystem fit to deliver sustainable renovation*

Increasing the volume of renovation around Europe needs a strong and competitive construction sector oriented towards innovation and sustainability to increase quality, lower costs, and reduce the duration of works through the implementation of industrialised technological solutions. Two other areas must be strengthened: the full integration of circularity principles across the value chain (using recycled/sustainable technologies chosen on the basis of a comprehensive life-cycle assessment approach) and digitalisation. Indeed, the uptake of digital tools by the construction sector remains low even if it allows to increase productivity, track building information, accelerate administrative procedures and physical works, consequently contributing to cost savings.

6. *Placing a smart, integrated, participatory, and neighbourhood-based renovation approach*

A well-integrated approach to renovation has been proved to deliver significant co-benefits in terms of user comfort and surplus energy, thanks to the introduction of smart systems and renewable sources.

Such buildings are transformed from consumers to producers of energy and their households become prosumers. In fact, the connection to the local grid allows feeding recharging points for e-mobility and reducing energy costs. This kind of synergies become more evident when scaled up to district and community levels: an increased system efficiency and flexibility, a co-management of generated energy and a more rational use of space for common areas and accessibility needs help the most vulnerable citizens to exit energy poverty and improve living conditions.

7. Matching style with sustainability

The Renovation Wave is also an opportunity to increase the aesthetical appeal of the existing building stock by starting a forward-looking process to match sustainability with style, to combine performance with inventiveness. The goal is to merge innovation and creativity to drive sustainable and affordable design across Europe through experiments on several pilot projects where art, culture, science, and technology can connect and develop new markets.

8. Using renovation as a lever to address energy poverty and accessibility

Inefficient buildings go hand in hand with energy poverty and social problems: tackling them is an urgent challenge for the European Union and its Member States. Besides the high energy bills, inadequate comfort, temperatures, air quality and sanitary conditions contribute to lower productivity and increase health problems. However, such poorly performing stock usually has to face persistent renovation barriers, from regulatory obstacles to complex condominiums' decision-making processes. The use of ESCOs and energy performance contracts seemed to work in case of limited ability to cover upfront costs, while financing solutions for low-income households must ensure cost neutrality (investment equal benefits) considering rent, energy and operating costs and local taxes. The use of standardised industrial retrofit solutions is essential in enabling cheaper and quicker interventions with limited impact on the social housing tenants.

9. Public buildings and social infrastructure showing the way

Public and privately-owned social housing, schools and hospitals can become a reference point for the industrialisation of the renovation process showing the co-benefits directly to the public. Guidance is needed to help public authorities analysing costs and returns on the investments in the built environment. Furthermore, the scope of existing legislative requirements must be extended to public buildings and more green public procurement criteria must be developed to increase the annual renovation rates.

10. Promoting the decarbonisation of heating and cooling

Many heating and cooling systems are old and inefficient: the decarbonization of the EU building stock must go through the modernisation of such systems to deploy local renewable energy and waste heat potential and to reduce the dependence on imported fossil fuels. Local authorities and utility companies play an important role in adjusting the regulatory framework, pushing towards the most efficient products, and creating the proper market conditions to address the barrier of high upfront capital investment. In addition, specific information about the building stock technical and energetic characteristics is necessary to decarbonise heating and cooling at national level.

Overall, the renovation wave promotes a **comprehensive approach tackling the retrofit challenge from different points of view**: from financial needs to technical assistance, from social problems to legal frameworks. Indeed, what emerges is that all aspects of the supply chain must be properly considered and integrated to find a feasible model able to overcome the abovementioned barriers. The Energiesprong programme, goes exactly in this direction, having social housing as initial target since it is

a valid starting point to experiment and showcase the benefits related to deep and industrialized interventions, as mentioned also in the renovation wave document.

However, for the EU Renovation Wave to be really implemented three strands of action are required:

1) **Updated European laws, directives and regulations.** In particular, the Energy performance in buildings directive (EPBD), the Energy Efficiency directive (EED), and the Renewable Energy Directive (RED) have been revised in 2018, being three of the 8 energy-related laws tackled by the **Clean energy for all Europeans package**, an rulebook adopted in 2019 to help decarbonising EU's energy system in line with the European Green Deal objectives. A further revision of all the three directives has been announced by the **Fit for 55 package**, a set of proposals presented in July 2021 to update the EU legislation with the aim of ensuring it's in line with the 2030 climate goals. While regulations have binding legal force throughout every Member State, directives must be transposed into national laws, within maximum two years. To date the three revisions have not been adopted yet but they have undergone the EU Commission proposal and the reference Committee[2] vote, waiting for the Trialogue[3] and the EU Parliament Plenary approval. However, the major proposals are expected to remain unchanged so it's worthing reporting and consider them as new 2030 targets to be met. (see paragraph 1.2 for more information)

2) **Funds and financing mechanisms** needed to double the annual renovation rate and ensure high-quality and deep interventions. Indeed, the private and public investment that will be mobilized is expected to be in the range of € 90 billion annually. This unprecedented challenge requires proper incentives to be effectively implemented. For this reason, the European Union is relying on various instruments geared towards directly support for building retrofit, such as grants; funds for research and innovation; technical assistance and the deployment of attractive financial products. (see paragraph 1.3 for more information).

3) **Long-term Renovation Strategies (LTRS)**, having a perspective of 30 years (till 2050), and **National energy and Climate Plans (NECPs)** for the period 2021-2030. The former were introduced by the 2010/31/EU EPBD version as attachments of National Energy Efficiency Action Plans (NEEAPs), which are the NECPs forerunners drawn up by EU countries, every 3 years, to show national improvements needed to reach the EU 2020 targets. The latter are firstly mentioned in the Regulation on Governance of the Energy Union and Climate Action (EU)2018/1999, agreed as part of the Clean energy for all Europeans package. According to the regulation (EU)2018/1999, the emphasis is on reaching the climate targets through the cooperation of individual Countries, each providing its contribution in a different way, taking into account both medium- and long-term objectives. The first NECPs had to be published by the end of 2019 and updated by mid-2023 and the LTRS, submitted in 2020 should be consistent with them.

[2] The EU Parliament numbers 20 committees, each handling a particular policy area. The committees examine proposals for legislation coming from the European Commission and give advice by producing reports.
[3] In the context of the European Union's ordinary legislative procedure, a trilogue is an informal interinstitutional negotiation bringing together representatives of the European Parliament, the Council of the European Union and the European Commission.

1.2 EU directives addressing the increase of buildings energy efficiency

The Energy Performance of Buildings Directive (EPBD, 2002/91/EC) is the first European legal act on energy policy in buildings, introduced in 2002, recast in 2010 and amended in 2018. It laid down the foundation for the setup of **minimum energy performance standards (MEPS)** in new buildings and in existing ones undergoing major renovation and having a useful floor area over 1000 m^2.

Indeed, 2002 EPBD mainly aimed to set a common and holistic approach for the calculation of buildings energy performances among all the Member States, despite a small group of countries (including Netherlands, France, UK, Germany, and Italy) have already defined some minimum requirements (mainly consisting of thermal insulation parameters), through the introduction of building codes[4] in the 1970s – 1980s. Under the EPBD provisions, instead, minimum standards are typically set as maximum amount of consumed energy (measured in kWh/m2 per year) applied to both new and large existing buildings undergoing major renovation. The latter is estimated based on outdoor and indoor characteristics of the building and the needs associated with a standardized use of it (Economidou *et al.*, 2020).

Minimum energy performance standards are the first step to limit buildings consumptions, but they do not incentivise the pursuit of high energy efficiency. For this reason, 2002 EPBD introduced the concept of **Energy Performance Certificates (EPCs)**, documents displaying the building's energy performance through an energy class value or a continuous scale rating system. EPCs must be made available to prospective buyers or tenants to guide their decision-making process towards more energy efficient choices and consequently to increase the market demand of energy renovation. Furthermore, if aggregated, they can be used to track and monitor the whole building stock performances, driving more conscious strategic choices.

In their first adoption, however, EPCs lacked access to trustworthy information leading to low reliability. With the 2010 recast, EPCs provisions were reinforced to make them more effective and Minimum Energy performance requirements were revised to ensure similar ambition levels among different Member States.

In this perspective, the **cost-optimal methodology** was introduced to consider (for the very first time) the whole building lifespan costs to set energy requirements. The cost-optimal level is defined as "the energy performance level which leads to the lowest cost during the estimated economic lifecycle" (art. 2.14) and it's used, by each country, to evaluate if its energy requirements deviate too much from the related economic optimum. The methodology implies to: define country's specific reference buildings; calculate the corresponding energy consumption without and with different levels of energy efficiency measures; evaluate the costs of the different scenarios (considering investment, maintenance, operation and energy produced) and choose the variant that optimizes both economic and energetic parameters, from a macroeconomic or a strictly financial perspective (Kristen Engelund *et al.*, 2012).

Finally, the 2010 EPDB recast brought in the concept of **Nearly Zero Energy Building (NZEB)** defined as "*building of very high energy performance, where the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources produced on-site or nearby*" (art 9). All Member States were requested to quantify their national definition according to the local conditions and the climatic benchmarks provided in the EU Commission Recommendation 2016/1318 of 29th July 2016. Regardless to the differences in the definition, 2010 EPDB established that all new buildings occupied by public authorities have to be NZEBs by the end of 2018, while the private ones by the end of 2020, with no prescription for buildings undergoing major renovation (Economidou *et al.*, 2020).

[4] Building codes is a set of rules that specify minimum standards for the construction of buildings. They are not legally binding but they, rather, serve as models becoming law when formally enacted by the appropriate government
tal or private authority.

For a better implementation of the EPBD requirements, in 2004, the European standardization body CEN introduced a common framework for the calculation of the total energy performance of buildings which was updated in 2010 resulting in a set of 52 EPB-standards to be used by Member States for the application of the Directive. The EPDB was finally amended in 2018 to be in line with the 2030 climate goals (Economidou *et al.*, 2020) .

First, it established more effective **Long-term Renovation Strategies (LTRS)**. The most recent one start from the NECPs 2030-roadmap to set up a long-term strategy supporting the building renovation towards a highly stock decarbonization by 2050. According to the 2018 EPDB provisions, LTRS must include an overview of the national building stock status associated to public policies, initiatives, incentives, and funds aimed at stimulating a cost-effective deep renovation of buildings, according to the archetypes, towards NZEBs standards and energy poverty fight. They also need to report estimations on expected energy savings and other benefits, measurable through progress indicators having 2030, 2040 and 2050 milestones, even though mandatory quantifiable targets are not prescribed (Economidou *et al.*, 2020).

For the first time attention was given to the introduction in the LTRS of optional national schemes for **Building Renovation Passports (BRP).** They are documents associated to specific buildings, outlining long-term renovation roadmaps organized in different stages to ensure a step-by-step coordination even in the case of changing ownership. They can also be linked to digital logbooks storing different types of information (available finance, energy bills, maintenance requirements, insurance plans, etc.) to be updated over time. A BRP is an evolution of the Energy Performance Certificate (EPC), since it is not limited to provide a static audit of the energetic building status, but it also supports the owner with a personalized renovation plan associated to the expected benefits. Indeed, one of the main barriers in addressing such interventions is the lack of knowledge about the process and its implications, together with difficulties in accessing finance. Unlike EPCs, renovations are not tackled from a technical point of view only, since BRPs are presented as home-improvement plans based on occupants' needs and situations to increase their engagement and stimulate retrofit operations (Buildings Performance Institute Europe - BPIE, 2017)

Focus of the amendment was also the introduction of common methodology to calculate the **Building Smart readiness indicator**, which is the ability of improving energy efficiency and comfort through the adoption of smart and automated technologies. Furthermore, attention was given to **e-mobility** by setting minimum requirements for electric recharge points, according to building sizes (Economidou *et al.*, 2020).

In December 2021, another revision of the Energy Performance of Buildings Directive (EPBD) has started, as part of the 'Fit for 55' package and as needed to deliver on the Renovation Wave (European Parliament, 2022).

For the first time, it mentions the concept of "(staged) deep renovation" as explained in paragraph 3.1. A new definition of "zero-emission building" is also provided in Article 2, meaning "*a building with a very high energy performance […] which contributes to the optimization of the energy system through demand-side flexibility, where any very low residual amount of energy still required is fully covered by energy from:(a) renewable sources generated or stored on-site; (b) renewable sources generated nearby off-site and delivered through the grid […]; (c) a renewable energy community […]; or (d) renewable energy and waste heat from an efficient district heating and cooling system […]*"(European Parliament, 2023a). With respect to nearly zero energy building, beside the more stringent requirement on renewable sources which must cover all the residual energy request, the demand-side flexibility concept is introduced. It means the ability to reduce, increase or shift a portion of energy demand within a specific duration in order to manage supply fluctuations given by the adoption of clean and renewable sources. Without this flexibility it would, indeed, be impossible to prevent the use of fossil fuel powered plants to meet peaks in demand.

In line with this new definition, by 2025, energy performance classes would be rescaled so that at least the 15% of national building stocks fall into class G (worst performing) on the EPC scale, ensuring comparable

efforts for future renovations among the different Member States. The remaining F to B classes shall be characterized by even bandwidth energy performance indicators, while Class A meet the new zero emission building standard.

Furthermore, to accelerate the renovation rate, ongoing provisions on existing buildings' energy performances will be made more ambitious, setting mandatory MEPS (European Parliament, 2023a):

- As far as public and non-residential buildings are concerned, they will need to reach class E by 2027 and Class D by 2030.
- Non-public residential buildings will need to undergo renovations to reach at least Class E by 2030 and Class D by 2033.

In addition, Member States shall ensure that EPC are issued for all public buildings and private buildings which are newly constructed, majorly renovated, sold, rented out, or for which a mortgage is refinanced, and a rent renewed. They should, also, establish a EPCs database and transfer the necessary data to the EU Building Stock Observatory, so that the Commission can build up a comprehensive and interoperable picture. For residential buildings, would be added the need to be equipped with certain monitoring functionalities to optimize management and life-cycle operation.

National building renovation plans would supersede the existing long-term building renovation strategies, establishing specific goals for renovating buildings by 2030, 2040, and 2050. They will be submitted every five years, to be reviewed by the Commission ensuring their seamless integration into the ten-year national energy and climate plans (NECPs).

Finally, by the end of 2023, the Commission would create a European Union (EU) framework for renovation passports through a delegated act. They would serve as valuable tools for building owners who are planning a multiple-steps renovation process, as well as potential buyers to keep track of future interventions.

In conclusion, the EPBD is the point of reference for energy performance standards in EU buildings and it kept setting more and more precise requirements over time to be aligned with the increasing stringent 2050 targets. However, it still relates closely with other aspects of EU climate and energy legislation, such as the energy efficiency overall framework and renewable energy sources.

The Energy Efficiency directive 2012/27/EU (EED) is the successor of the Energy Services Directive 2006/32/EC (ESD) and it has been amended in 2018 with the approval of 2018/2002/EU to set the energy efficiency targets for 2030: primary and/or final energy savings moved from 27% to 32,5% (with respect to 2030 consumption projections from the European Commission's 2007 baseline scenario), updating the first European NDC.

To reach the goal it's necessary to implement appropriate strategies to remove the main barriers to energy efficiency. While the EED does not stipulate any obligatory actions, it mentions several possible solutions to tackle **split incentives** including regulatory measures and various financial and fiscal schemes. Several Member States have introduced information mechanisms through national and local energy agencies offering advice to building owners and public authorities. Others have also offered a broad range of financial incentives to facilitate investments: they go from low or zero interest loans to subsidies (grants, tax deduction, white certificates). However, some other countries have no yet relevant measures in place highlighting the need for further policy action in this area.

What, instead has become mandatory with the EED (2012/27/EU) is the introduction of **consumption-based measuring and billing** of heating, cooling, and domestic hot water in multi-apartment buildings, to promote a more active engagement of building occupants towards energy saving practices. The idea behind is that providing consumption feedback to energy users can drive behavioural change, leading to final energy

consumption reduction. The rule adoption in the EU Member States led to some consumer protection issues solved by adjustments made in the 2018 amendment (Economidou *et al.*, 2020).

Since, the 2020 decision to increase GHG emissions reduction target from 40 % to 55 % by 2030 requires much greater energy savings, also the EED has been reopen soon after its last amendment as part of the "fit for 55" package (European Parliament, 2023b). The revision states that a further reduction in energy consumption of at least 9% by 2030 is needed, meaning a 36% savings in final energy consumption (FEC) and 39% savings in primary energy consumption (PEC) by 2030 (see ***Appendix A*** for energy flows definitions). Both targets must be met, setting the limits of 787 Mtoe (FEC) and 1023 Mtoe (PEC), significantly lower than 2018 EED bounds of 846 Mtoe in FEC and 1128 Mtoe in PEC.

Other changes, relevant and connected to the building sector, are stated below:

- At least 3% of the floor space of all buildings owned by public bodies least 3 % must be renovated annually to nZEB standards.
- Each Country shall take appropriate measures (stated in the upcoming NECPs) to promote and facilitate an efficient use of energy by final users. In particular, one-stop shops mechanisms should be created to provide technical, administrative and financial assistance for energy efficient renovations.
- Member States are obliged to further support people affected by energy poverty, and social housing tenants.
- efficient heating and cooling system (HCS) are clearly defined based on the share of renewable energy, waste and cogenerated heat used. Such minimum portion would regularly increase to meet 2050 targets.

Heating and cooling is the most cross-cutting topic, touching (from different points of view) all the energy-related directive, especially the one on renewable sources and objectives.

The Renewable Energy Directive (RED) is the third EU renovation-related legal act, in the path towards carbon neutrality (European Parliament, 2023c). Indeed, energy efficiency measures have strong synergies with the EU renewable energy target: the more energy is saved, the easier it is to satisfy the remaining needs with renewable energies sources (RES). In its first emission, 2009/28/EC or RED I, it established a series of measures to help the EU reach its **20% renewable energy target by 2020** through binding minimum national targets calculated in terms of the Renewable Energy Sources (RES) share of gross final energy consumption (varying from 10 % in Malta up to 49 % in Sweden).

Directive 2018/2001 (RED II) is a full recast of RED I to set 2030 goals to 32% of renewable energy in the EU, without setting new binding targets on individual Member States. Going more deeply into building-related articles, the directive recommends the use of renewable heating and cooling systems. Indeed, each Member State shall increase the share of renewable energy in the sector by an indicative 1,1 percentage points starting from the share of RES in the heating and cooling sector in 2020.

As the EPBD and the EED, also the RED directive is undergoing a revision process to meet the new 2030 55% GHG target (European Parliament, 2023c). The RED II will be only an amending directive of RED I and now a full recast because of the relatively short time that has lapsed since the last adoption. Four are the most relevant changes to be highlighted:

- a minimum 40 % share of energy from RES in final consumption by 2030 (binding at EU level with indicative national contributions)
- an obligation to phase out support for electricity production from biomass from 2026.
- an increased RES ambition in the heating and cooling sector via an **indicative EU target of a 49 % share of RES in the heating and cooling of buildings by 2030**

- the +1.1 % annual RES increase as a binding baseline and no more as indicative target plus a mandatory assessment of the RES potential in the sector by each Member State.

Finally, as part of the "fit for 55" package, the **EU emissions trading system (ETS)** will be also revised introducing specific schemes for the buildings and road transport sectors. Indeed, until now, they have been covered by the **Effort-sharing Regulation** only, which sets binding obligations on individual Member States to make GHG emissions reductions in those areas where the ETS scheme does not apply. The ETS introduction is even more powerful because it would establish a market-based mechanism that assigns a monetary value to CO2 emitted, providing a strong financial incentive to decarbonize buildings in a cost-effective manner. Under this scheme, companies (intended as distributors that supply fuels, not households) acquire or receive allowances that correspond to their CO2 emissions. As a result, the production of power from coal and other fossil fuels becomes more expensive, while clean energy sources become comparatively more attractive. Indeed, the EU ETS operates on a "cap-and-trade" principle, setting an annual limit on allowable CO2 emissions, which is gradually reduced over the years. Companies must hold European Emission Allowances (EUAs) for each metric ton of CO2 emitted within a calendar year. If they exceed their allocated emission allowances, they are subject to fines. This incentivizes companies to invest in energy efficiency measures, as they can sell surplus allowances (Appunn and Wettengel, 2023).

1.3 EU funding dedicated to energy efficiency and building renovation

To meet the goals set out by the European Union in relation to the energy transition, especially after the ongoing revision of the EPBD, EED ad RED directives, the building environment is expected to undergo a substantial transformation over the next few decades. However, energy renovations are expensive and owners or building managers often lack the means to finance them. To address major financial gaps, at EU level, **several funding streams are available**, ensuring that the investments needed are enabled at the necessary scale. Indeed, as stated by the Renovation Wave "*the EU's recovery instrument NextGenerationEU, alongside the EU's Multiannual Financial Framework, will make available an unprecedented volume of resources that can also be used to kick-start renovation for recovery, resilience and greater social inclusion*" (European Commission COM(2020) 662 final, 2020a).

The Multiannual Financial Framework (MFF) is the EU's 2021-2027 long-term budget, made up of **€1.211 trillion**[5] that will aid the transition towards a modern and more sustainable Europe. The EU's MFF sets out the multiannual ceilings of expenditure that can be spent on various policy areas to ensure that annual budgets remains predictable and effective. The programs funded under the Multiannual Financial Framework are grouped into seven policy-related expenditure categories which are: Single Market, Innovation and Digital; Cohesion, Resilience and Values; Natural Resources and Environment; Migration and Border Management; Security and Defence; Neighbourhood and the World; European Public Administration (European Commission, 2021b).

NextGenerationEU (NGEU) is a **€806.9 billion** temporary instrument designed to boost post-pandemic recovery, helping repair the immediate economic and social damages and making EU fit for the forthcoming challenges (European Parliament, 2020). Its main centrepiece is the **Recovery and Resilience Facility (RRF)** which is aimed at providing grants and loans to support reforms and investments in the EU Member States at a total value of **723.8 billion**. The remaining NGEU budget will reinforce other existing MMF programs and policies for a total amount of **83.1 billion**.

[5] All the budgeted values are reported in current prices, dated according to the publication of the related sources.

Both the MFF and the NGEU are key components of the **European Green Deal Investment Plan (EGDI)**, which will mobilize at least €1 trillion to achieve 2030 environment-related goals set by the European Green Deal. Extrapolated over ten years, the **EU budget is supposed to provide € 500 bn**, since it will trigger Member States' and private actors' additional co-financing for the remaining half a trillion (European Commission, 2020).

Within the broader climate-oriented investments, focusing on renovation, the European Union will activate various funding instruments having three main scopes, as stated by the COMMISSION STAFF WORKING DOCUMENT (European Commission COM(2020) 662 final, 2020b) accompanying the Renovation Wave strategy.

1. Support direct investments in quality building energy efficiency

- Under the MFF "Cohesion, Resilience and Value" category, the **European Regional Development Fund (ERDF) and the Cohesion Fund (CF)** represents the largest EU source for direct support to a greener Europe, with a minimum allocation of **€ 85,6 bn**, among which almost **€ 22 bn** have been planned for energy efficiency measures.
  The ERDF "*aims to strengthen economic, social and territorial cohesion in the European Union by correcting imbalances between its regions"* (Directorate-General for Regional and Urban Policy, 2023f). The overall € 226,1 bn funds are proportionally allocated to all EU Member States according to three categories of regions (less developed, more developed, in transition). 30% of the total amount (€ 67,8 bn), independently from the typology of region, must be addressed to "a greener, low-carbon transitioning towards a net zero carbon economy and resilient Europe" (PO2). In particular, the 2021-2027 planned EU financing for energy efficiency reaches **€ 18,8 bn** (Directorate-General for Regional and Urban Policy, 2023c) , to be added to the **€ 152 m** coming from European Territorial Cooperation – Interreg (Directorate-General for Regional and Urban Policy, 2023d). Indeed, almost € 10 billion of ERDF budget, are shared between Interreg crossborder, transnational, interregional and outermost programs which "*promote cooperation between regions and countries, in and outside the EU, to help their economic and social development and tackle the obstacle of borders*". The amount dedicated to deep renovation in housing, public infrastructure and enterprises is about **€ 14 bn** coming from the ERDF and **€ 43 m** coming from Interreg. The comparison with the budget targeting new energy efficiency buildings (slightly above € 1 bn), shows the increasing importance policies are giving to renovation with respect to new construction.
  The CF "*provides support to Member States with a gross national income (GNI) per capita below 90% EU-27 average to strengthen the economic, social and territorial cohesion of the EU"* (Directorate-General for Regional and Urban Policy, 2023a). For the 2021-2027 period, the € 48,0 bn budget concerns Bulgaria, Czechia, Estonia, Greece, Croatia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Portugal, Romania, Slovakia, and Slovenia. 37% of the whole financial allocation (€ 17,7 bn) should contribute to climate objectives, of which **€ 2,8 bn** have been planned to tackle energy efficiency only (Directorate-General for Regional and Urban Policy, 2023b). The amount dedicated to deep renovation in housing, public infrastructure and enterprises is about **€ 738 m,** being 12 times the budget targeting new energy efficiency buildings (slightly above € 60 m).

- Still under the MFF "Cohesion, Resilience and Value" category, the **Recovery and Resilience Facility (RRF)** is the largest EU funding source for energy efficiency (European Commission, 2021b). The RRF will be distributed according to National Recovery and Resilience Plans (NRRPs) prepared by each Member State, in line with some EU agreed criteria. In particular, each Country must dedicate at least 37% of the expenditures of its NRRP to measures contributing to climate objectives. So far, the investments proposed have exceeded this target reaching the 40%. More in detail, the approved plans dedicate a significant amount of funds, **€ 65,3 bn**, to energy efficiency, reflecting the required

priority to decarbonize the building stock (European Commission, 2023). It corresponds to 13.4% of the total expenditures in the NRRP and to the 25% of the climate-related ones; a whole third will be invested by Italy only. Most of the spendings have the objective to achieve medium-depth level renovation: **€ 31 bn** target private buildings, **€ 23 bn** support renovations of public buildings, while the remaining € 10.6 bn will be invested in the construction of new highly energy efficient public and private buildings.

- Due to the hardships and energy market disruption caused by the war in Ukraine, **REPowerEU** has been introduced among the 2027 EU policy targets. It is *"a plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition"* (European Commission, 2022c). Nowadays imports costs nearly 100 billion euros per year and the investment needed to reach the objective is estimated to be around € 210 bn, of which **€ 56 bn** for energy efficiency and heat pumps (European Commission, 2022a). The main funding source comes from RRF loans since REPowerEU will be added to National Recovery and Resilience Plans (RRP) with country-specific recommendations. Furthermore, the transfer possibility from Cohesion Policy funds (among which ERDF and CF) to RRF will be increased from 5% to 12,5%, with an extra 7,5% (€ 26,9 bn) to be spent exclusively on REPowerEU objectives (European Commission, 2022c). Finally, new RRF grants will be made available by auctioning Emission Trading System allowances, currently held in the Market Stability Reserve[6] and worthing around € 20 bn. As such, the ETS not only encourages the reduction of fossil fuels, but it also helps raising the necessary funds to achieve energy independence.

- The last renovation-related program under the "Cohesion, Resilience and Value" category is **REACT-EU**, which *"aims to bridge the gap between the immediate emergency response in the context of the COVID-19 pandemic and its social consequences, and long-term recovery"* (Directorate-General for Regional and Urban Policy, 2023g). It is financed by NGEU recovery plan which provide € 50,6 bn of fresh resources to existing cohesion policy programs for the years 2021 and 2022, proportionally allocated according of the economic and social impact of the crisis on the EU countries. These additional funds are primarily channelled through the ERDF: **€ 2,5 bn** is the amount planned to be invested in energy efficiency with its majority (€ 2,1 bn) targeting renovation of public infrastructures and housing stock (KURME and WALSH, 2023).

- Switching to the **"**Natural Resources and Environment" MFF category, the **Just Transition Fund,** which is the first pillar of the Just Transition Mechanism, "*aims at alleviating the economic, environmental and social costs of the transition towards climate neutrality, for the benefit of the territories that are most negatively affected by the transition and in line with the objective of achieving EU climate-neutrality by 2050 in an effective and fair manner*" (European Parliament, 2021). The € 19,2 bn of JTF (€ 8,4 bn from MFF and € 10,8 from NGEU) come in addition to the EU's budget already allocated to reduce territorial disparities in the framework of the Cohesion Policy (notably the ERDF and the CF). Among others, the JTF supports investments in energy efficiency for a total planned budget of **€ 767 m,** of which **€ 551 m** targeting deep renovation in housing, public infrastructure, and enterprises (Directorate-General for Regional and Urban Policy, 2023e).

- Moving off the MFF and NGEU budget, **the Modernisation fund** is "*a dedicated funding programme to support 10 lower-income EU Member States in their transition to climate neutrality by helping to modernise their energy systems and improve energy efficiency"* (Directorate-General for Climate

[6] The market stability reserve began operating in January 2019 to collect the surplus of emission allowances that was built up in the EU emissions trading system (ETS) since 2009 (largely due to the reduced emission happened during the economic crisis, which reduced emissions more than anticipated, leading to lower carbon prices). The reserve is needed to improve the system's resilience to major shocks, safeguarding the ability of the ETS to meet more demanding emission reduction targets cost-effectively.

Action, 2023). The beneficiary Member States are Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia. The Fund is recognised in the European Green Deal Investment Plan as one of the key instruments to reach the climate goals. It is partially funded by the revenues coming from the auctioning of 2% of the total allowances for 2021-2030 under the EU Emissions Trading System (worthing around € 20 bn) plus additional allowances transferred by the beneficiary Member States that opted to do so.

As stated in the ETS Directive, at least the 70% of resources must be invested in 5 priority areas: generation and use of electricity from renewable sources; improvement of energy efficiency (including transport, buildings, agriculture, waste and excluding solid fossil fuels); energy storage; modernisation of energy networks (including district heating pipelines, grids for electricity transmission); and support to a just transition in carbon-dependent regions in the beneficiary Member States. So far, the confirmed investment proposals amount to around € 5 bn, of which the 10% addresses energy efficiency in buildings. Due to the increasing stringent targets imposed by the EPBD revision, it's reasonable to estimate that this percentage might increase, reaching the 20%, which means a maximum of **€ 4 bn** in the period 2021 – 2027 (Modernisation Fund – secretariat, 2023).

2. Leverage private investment at a larger scale and fund technical support services

- Within the "Single market, innovation and digital" MFF category, the **Invest EU Fund** is a market-based and demand-driven centralised instrument, with a strong financial capacity allowing the delivery on EU policy objectives and the minimization of overlaps. It is expected to trigger at least €372 billion of public and private investment through an EU budget guarantee of €26.2 bn to increase the risk-bearing capacity of the European Investment Bank (EIB) Group and other financial institutions (Directorate-General for Economic and Financial Affairs, 2023). **€ 9.9 bn** are allocated to sustainable infrastructure policy window according to the investment proposals made by Member States and approved by the Investment Committee throughout the years. A part of this budget will tackle energy efficiency and renovation projects focused on energy savings and the integration of buildings into a connected energy source, storage, digital and transport system. The fund is the first pillar of the Invest EU Programme which "*supports sustainable investment, innovation and job creation in Europe".* The second pillar is the **InvestEU Advisory Hub,** created to "*acts as the single-entry point for project promoters and intermediaries seeking advisory support and technical assistance related to centrally managed EU investment funds"* (European Investment Bank, 2023b). It consolidates the access to 13 existing advisory services, including ELENA, the European Local ENergy Assistance born under the Horizon 2020 programme and focused on energy efficiency and renewable energy investments targeting buildings and innovative urban transport. Typically, ELENA supports renovation investment above €30 million with a three-year implementation period so it encourages and supports the aggregation of different projects to increase the attractiveness for contractors and financers (European Investment Bank, 2023a).

3. Boost research and innovation and address market barriers to building renovation

- Still within the "Single market, innovation and digital" MFF category, **HORIZON Europe** "*is the EU's key funding programme for research and innovation with a total budget of € 95.5 bn. It tackles climate change, helps to achieve the UN's Sustainable Development Goals, boosts the EU's competitiveness and growth and supports dispersing excellent knowledge and technologies*" (European Commission, 2021a). The programme provides financial support, primarily in the form of grants, with different co-financing rates depending on the project type. Funding opportunities are set out in biannual work programmes targeting different clusters: Health; Culture, Creativity and Inclusive Society; Civil Security for Society; Digital, Industry and Space; **Climate, Energy and Mobility**;

Food, Bioeconomy, Natural Resources, Agriculture and Environment. Energy transition of buildings is one intervention area of Climate, Energy and Mobility cluster which has a total budget of **€ 15,1 bn** to better understand Climate Change causes, evolution, risks, impacts and opportunities (Directorate-General for Research and Innovation, 2023).

- Under "Natural Resources and Environment" MFF category the **LIFE programme** is the EU's funding instrument for the environment and climate action. In particular, its **Clean Energy Transition (CET) sub-programme** "*aims at facilitating the transition towards an energy-efficient, renewable energy-based, climate-neutral and -resilient economy by funding coordination and support actions across Europe*" (European Climate Infrastructure and Environment Executive Agency, 2023). A part of the nearly **€ 1 bn** CET's budget will provide tailored support to holistically address and remove market barriers to renovation by setting a favourable enabling framework among Member States public and private actors. Call for proposals are published every year tackling specific challenges. The related summitted proposals are then evaluated and scored against selection criteria to award the predefined grants.

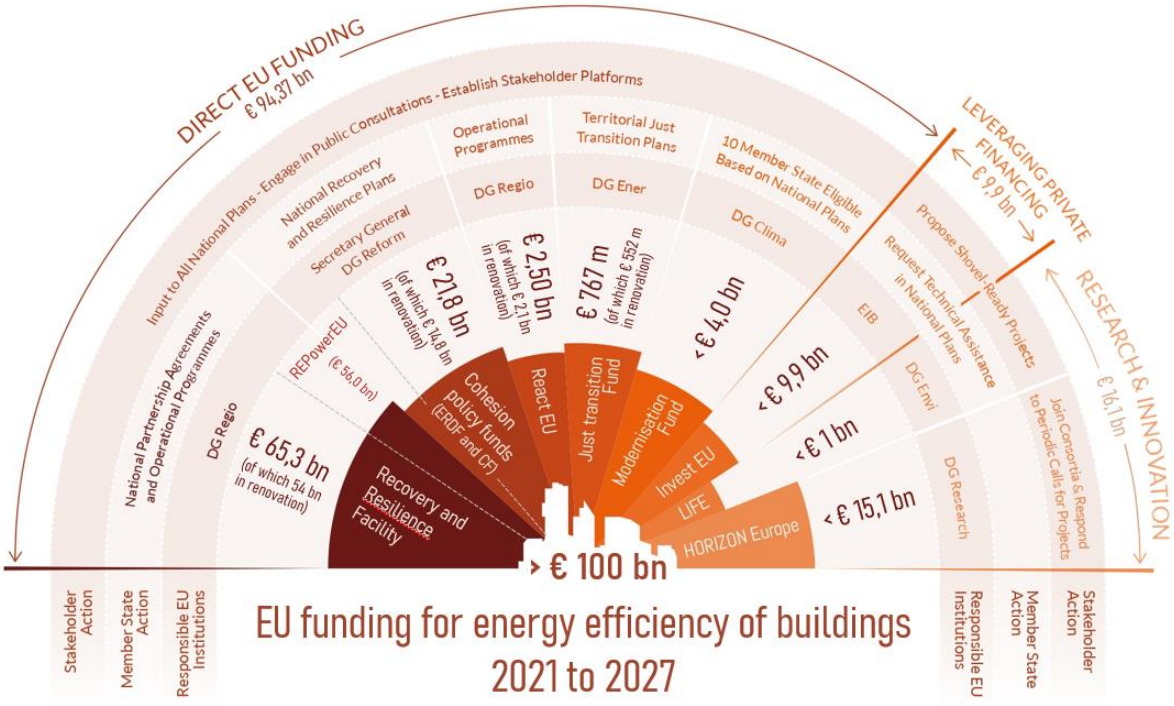


Figure 2 *Summary of funding allocated by the EU for energy efficiency of buildings between 2021 and 2027*

A comprehensive visual on the EU funding dedicated to energy efficiency from 2021 to 2027 is shown in **Figure 2**, which is a quantitative adaptation from the Renovate Europe[7] infographic (Renovate Europe, 2022). Overall, as described above, **more than € 100 bn** will be allocated, representing about the 20% of the EU budget assigned by the **European Green Deal Investment Plan** to achieve 2030 climate-related goals.

In addition, under the amending Energy Performance of Buildings Directive (2018/844/EU), Member States should provide a list of national measures for funding energy efficiency. These lists can be found in their long-term renovation strategies and are updated every 3 years.

Furthermore, expanding the time horizon, with the introduction of a new ETS for buildings and transport, a additional fund will be introduced to provide support to vulnerable groups most affected by higher fossil fuel

[7] Renovate Europe is political communications campaign launched in 2011 by EuroACE, the European Alliance of Companies for Energy Efficiency in Buildings, with the ambition to reduce the energy demand of the EU building stock by 80% by 2050 through legislation and renovation programs.

prices. The so-called **Social Climate Fund** will financially help tackle energy poverty and improve access to low-emission mobility (General Secretariat of the Council, 2023). Indeed, the revenues coming from the sale of allowances to companies providing fossil fuels (for heating and transport) will be put in the fund for a total estimation of **€ 65 bn** to be used by Member States between **2026 and 2032**. Among others, funding should be used to invest in increased energy efficiency, decarbonization of heating and cooling and integration of renewable sources. Pending the impact of those investments, it could also finance direct income support for exposed households.

The relevant budget share taken by energy transition of buildings shows, once again, the priority given to renovation investments in the next decade.

CHAPTER TWO
Environmental and social challenges due to residential energy use

As emerged in Chapter one, housing is one of the main targets of climate-related European policies which set clears and ambitious goals. Indeed, residential energy consumptions are currently too elevated and need to be reduced to contain GHG emissions and energy poverty. This is more urgent than ever for social housing, those vulnerable households experience, unbearable energy bills and extreme discomfort due to high levels of energy inefficiency. As a rule, in this chapter, the reported data are referred to 2020 because they are the most widely available. However, since energy consumptions were highly affected by the Covid-19 crisis and energy prices have been strongly impacted by the Russia-Ukraine war, 2021 and 2022 data are also cited, when relevant.

2.1 Overall European housing energy consumptions and emissions

Across the EU there are 12 million non-residential buildings and 119 million residential buildings of which 42% apartments, 34% detached dwellings, 24% semi-detached dwellings, mostly located in urban centres (43%). **Around 48 million, representing the 40%, were built pre-1970, so before the widespread introduction of building codes and energy efficiency measures.** It is, also, estimated that 35% of the whole stock has an EPC rating between D and G, with around 30 million building units representing the sum of the 15% worst-performing ones across all the Member States (Zangheri *et al.*, 2021).

These data suggest that residential buildings still highly contribute to the overall energy demand. Indeed, they cover around the 28%, being as energy demanding as transport and more than industry (26%), as reported in **Table 1**. However, if we consider all buildings, a share of services, which include the energy needs of non-residential stock, should be added to the residential one, making it the most consuming sector. Furthermore, looking at numbers from 2015 (which is the reference year for the renovation wave targets), it can be noticed that in 2020 residential buildings consumed more than 2015. This is due to Covid-19 pandemic which forced people at home, reducing, on the other hand, industry, transport, and services activities. Indeed, looking at 2021 first available data (European Commission DG Energy, 2023) final residential energy consumption raised to 262 Mtoe, while transport and services went back to 2015 levels to face the recovery. The reported values show that **housing is far from reaching 210 Mtoe (which corresponds to a 14% reduction in its final consumption)**: effort in energy efficiency and deep renovation is needed to obtain a decrease of 2% a year towards 2030 objectives.

Table 1 *final energy consumption in Europe divided by sector, 2015 and 2020 values. Source:* (European Commission DG Energy, 2022)

SECTOR	CONSUMPTION 2015	CONSUMPTION 2020	EU SHARE 2020
Industry	234 Mtoe	231 Mtoe	26%
Transport	272 Mtoe	251 Mtoe	28%
Residential	**245 Mtoe**	**248 Mtoe**	**28%**
Services	129 Mtoe	121 Mtoe	14%
Agriculture and Fishing	26 Mtoe	30 Mtoe	3%
Other	4 Mtoe	4 Mtoe	0,4%
TOTAL	**909 Mtoe**	**886 Mtoe**	**100%**

The total 2020 final energy consumption can, instead, be compared with the **2012/27/EU EED target of 959 Mtoe**, resulting from the technical adaptation of the amount written in the Directive (1078 Mtoe), due to the withdrawal of United Kingdom. Also, the 886 Mtoe value has to be recalculated using the methodology on energy balance that was in place in 2012, getting to 907 Mtoe which are comparable with the target, as shown in **Figure 3** (European Commission DG Energy, 2022). As expected, the COVID-19 pandemic had a significant impact on energy consumption levels in Europe, since various activities came to a halt for several months. Indeed, until 2019, the EU-27 had managed to reduce energy consumption to a level 2.0% above the 2020 target while in 2020 it suddenly exceeded the target, despite previously being off track.

Thanks to the significant drop in energy consumption in 2020, EU demonstrated an average annual decline in final energy consumption of 8.9 Mtoe from 2005 to 2020, equivalent to a 0.9% reduction annually, which is the exact rate needed to achieve the current 2030 energy efficiency target of at least a 32.5% reduction. However, the 940 Mtoe rebound of final energy consumption experienced in 2021, during the post-pandemic recovery, necessitate much greater subsequent cuts to bridge the gap. Furthermore, the **efforts planned so far in the National Energy and Climate Plans aim for 885 Mtoe, which is 4.6% above the current target of 846 Mtoe by 2030** (see **Figure 3**) and even further from the 36% reduction proposed in the ongoing EED revision: all sectors require a quick and significant downsizing of their respecting energy needs (European Environment Agency, 2021).

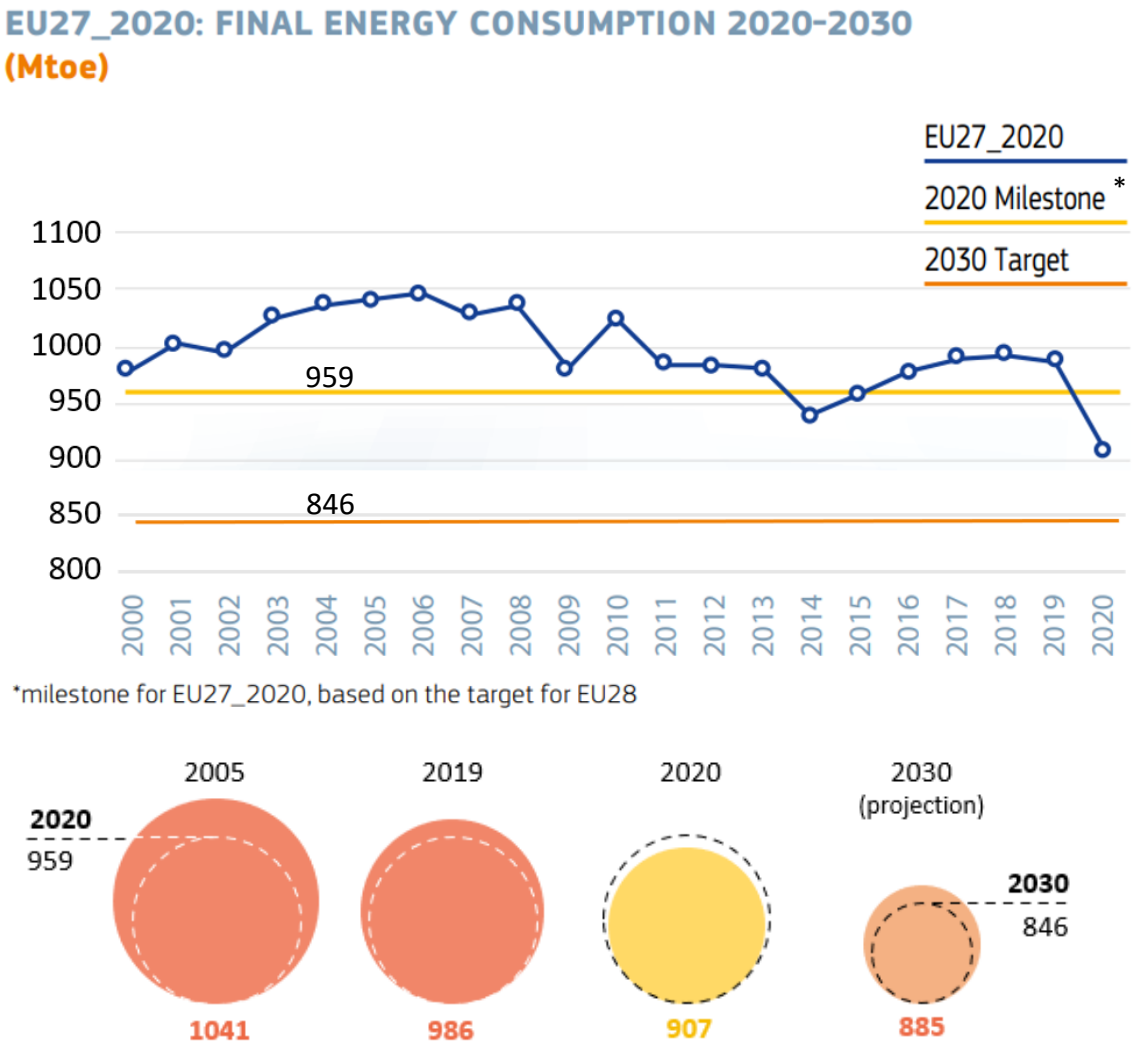


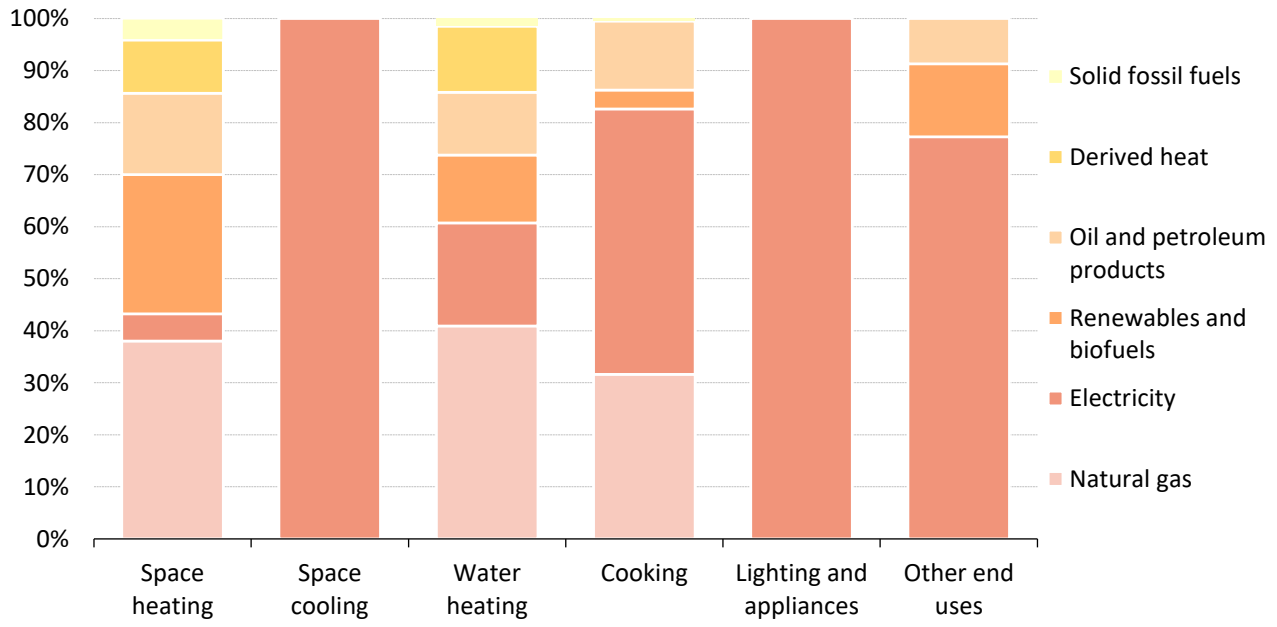
Figure 3 *Final energy consumption trends with respect to 2020 and 2030 targets. Sources:* (European Commission DG Energy, 2022)*;* (European Environment Agency, 2021)

Going into details for the residential category, the above-mentioned 28% EU share, which corresponds to about 248 Mtoe of final energy consumed, employs several types of fuel for different types of households end-use, as detailed in **Table 2**.

Table 2 *Share of fuels in the final energy consumption of the residential sector by type of end-use, EU, 2020. Adapted from:* (Eurostat, 2022b).

Type of end-use ⇨		Space Heating	Space cooling	Water Heating	Cooking	Lighting and appliances	Other end uses
Fuel type ⇩	ENERGY USE	62.8%	0.4%	15.1%	6.1%	14.5%	1.0%
Solid fossil fuels	2.8%	91.0%	0.0	7.8%	1.1%	0.0	0.0
Derived heat	8.2%	77.0%	0.0%	23.0%	0.0	0.0	0.0
Oil and petroleum products	12.3%	78.2%	0.0	14.6%	6.5%	0.0	0.7
Renewables and biofuels	20.3%	87.9%	0.0	10.3%	1.2%	0.0	0.7
Electricity	24.7%	13.1%	1.5%	12.0%	12.5%	57.9%	3.0%
Natural gas	31.7%	74.6%	0.0	19.3%	6.1%	0.0	0.0

Considering the same data from another prospective, **Graph 1** shows the proportional quantity of each fuel required by each type of energy end-use.



Graph 1 *Share of different fuel used by each type of end-use, in the final energy consumption of the residential sector, EU, 2020. Source:* (Eurostat, 2022b).

Overall space heating is the end-use that needs more energy (above 60%) and it uses the highest share (around 75%) of natural gas, which is the most consumed unrenewable fuel: this is why the RED directive set an ambitious target of 49% share of RES in the heating and cooling of buildings by 2030 (Eurostat, 2022b).

It is followed by both domestic hot water and lighting/appliances (15% each). On the contrary, space cooling doesn't reach the 1% since it's needed only in a few countries, located in the South of Europe.

The high share of renewables (20%) especially for the heating system shows a positive trend, towards 2030 objectives. However, in order to properly analyse the table and the graph, it's important to understand what is classified as renewable. Eurostat explicitly states that the share of energy from renewable sources "*is measured as the energy actually consumed by end-users (after transformation from primary energy form to the end-use form). […] In other words, renewables in this accounting do not include electricity and derived heat produced from renewable energy sources. Consequently, the calculated result using final energy consumption underestimates the share of energy from renewable sources*" (Eurostat, 2023a). This could be easily deduced by looking at the type of fuel consumed by lighting and appliances: it appears 100% electricity while, nowadays, a significant share is covered by photovoltaic panels. This share should be included among the renewable sources to be differentiated from the non-renewable electricity distributed by the public grid, allowing a better assessment of buildings energy efficiency.

Indeed, in the EU 39% of electricity generation comes from renewables and biofuels (European Commission DG Energy, 2022). **Transposing the proportion to the residential sector, the renewable share would reasonably increase by 10% (being the 39% of 24,7%), to reach the 30%.**

It clearly emerges the need to drastically reduce the operational energy demand of the whole building sector by improving the performances of both the envelope and the technical systems with a **particular attention to heating and cooling** (due to the -18% target set by the Renovation Wave).

Shifting from consumption to energy related GHG emissions, the residential sector lowers its share to 12,8%, with 318 Mt of CO2 equivalent produced (as shown in **Table 3**). However, in this categorization only the greenhouse gases released at building level are included (such as gas boilers) while electricity and derived heat generated in the power production plants are considered within energy industries. Since they represent around the 33% of households' consumptions, they make the emission share raise to over 15% (around 380 Mt CO2e). In line with consumption trends, in 2021, the residential sector didn't experience significant emissions rebound with respect to energy industries and transport which re-increased their activities after the pandemic slow down. However, **to meet the Renovation Wave goal of decreasing greenhouse gas emission by 60% with respect to 2015 levels, housing must reduce building level releases of around 20 Mt Co2e per year.** It implies a yearly rate of 6,5% which is possible only combining energy efficiency measures and the implementation of renewable sources to cover the remaining needs.

Furthermore, **Table 3** also reports "**manufacturing industries and construction**" sector which appears to be as pollutant as the residential one, underlying the importance to monitor and control the emissions associated to the whole building life cycle, including construction, renovation and disposal phases: the so-called **embodied carbon**[8]. Indeed, facing a growing number of retrofit interventions in the next decades requires the adoption of production, transportation and installation processes that cause as little harm as possible to the environment. Attention must be given to long-lasting, circular, and effective renovations, able to contribute to the overall GHG emissions reduction over time.

Moving to the broader picture, unlike the rollercoasting trend of energy consumptions, total GHG emissions (energy and not energy related plus international aviation) show a **constant decline having reached 32% below 1990 levels in 2020** (**Errore. L'origine riferimento non è stata trovata.**) (European Commission DG Energy, 2022).

[8] Embodied carbon represents the millions of tons of carbon emissions released during the lifecycle of building materials, including extraction, manufacturing, transport, construction, and disposal.

This substantial reduction has been strongly driven by the substitution of coal with gas and renewable energy sources in the EU power sector and it's confirmed by 2021 data (3541 Mt Co2e) which are a bit higher than 2020 ones but still lower than 2019 values (European Commission DG Energy, 2023). In December 2020 the updated NDC version enhanced the GHG emission target to **55%** without contribution from international credits, in line with the evolution of the EU's internal strategies as stated in the **Climate Target Plan 2030.**

Table 3 *EU GHG emissions in 1990, 2015 and 2020. Source:* (European Commission DG Energy, 2022)

SECTOR	GHG EMISSIONS [Mt CO_2e]			2020 SHARE
	1990	2015	2020	
Energy Industries	1438	1113	781	31%
Manufacturing industries and construction	727	427	405	16,3%
Transport	673	795	721	29%
Commercial/ institutional	172	134	117	4,7%
Residential	**449**	**332**	**318**	**12,8%**
Agriculture/ forestry/ fisheries	91	75	77	3,1%
Other sectors	22	7	6	0,3%
Other Combustion and Fugitive Emissions	152	78	62	2,5%
TOTAL (energy related)	**3724**	**2960**	**2488**	**100%**
Not energy related	1122	856	810	//
International aviation	54	109	56	//
TOTAL	4901	3924	3354	//

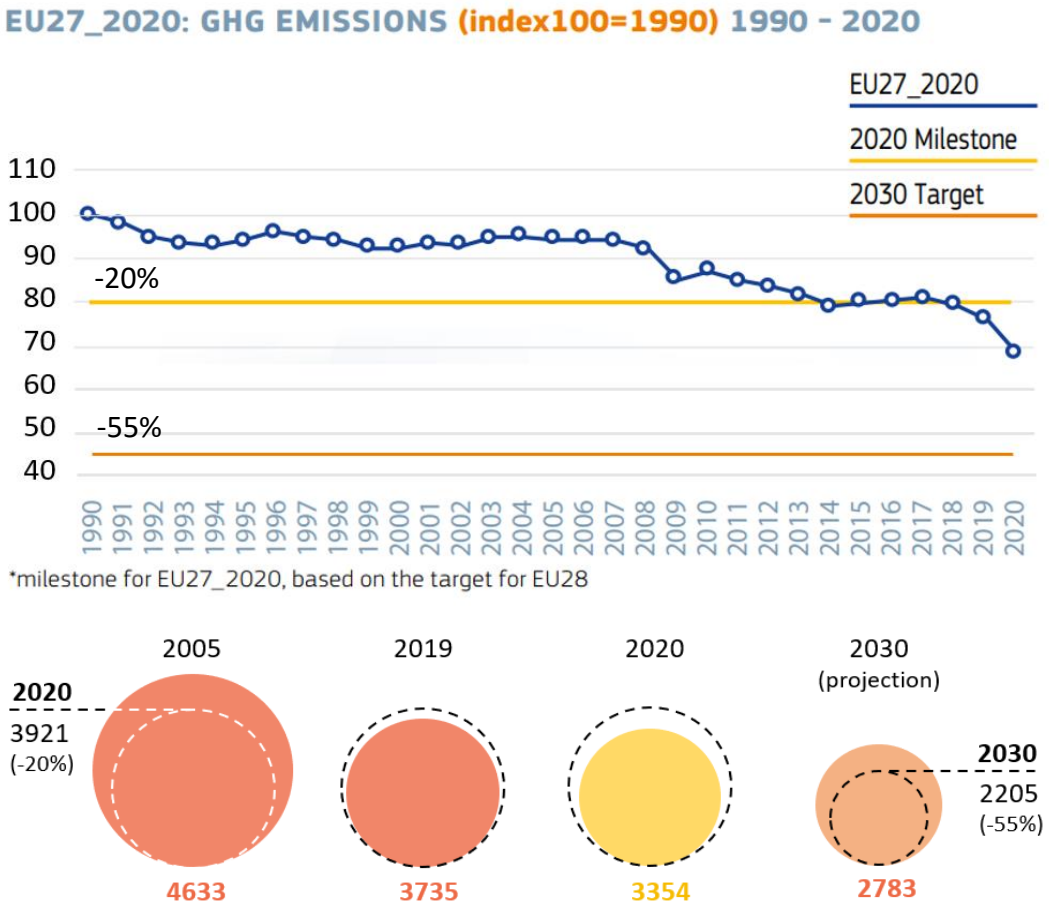


Figure 4 *GHG emissions with respect to EU 2020 and 2030 targets.*
Sources: (European Environment Agency, 2021; European Commission DG Energy, 2022)

However, to achieve the -55% target, there would need to be an average annual decrease of 101 Mt CO2e, which is roughly double the average reduction observed between 1990 and 2020 (-53 Mt CO2e). This implies that **between 2020 and 2030, the decline in greenhouse gas (GHG) emissions must be increased since projections indicate an expected reduction of 41 % by 2030 through the introduction of additional policies and measures** (European Environment Agency, 2021)**.** The comprehensive "Fit for 55" policy package will be crucial to set all relevant sectors on the path to 2030, and the building one will be one of the most affected (as deeply explained in chapter 1).

2.2 Overview on the European energy poverty condition

High energy consumptions in buildings bring with them not only unsustainable CO_2 emissions, but also unbearable energy bills. This phenomenon is called **energy poverty** but, despite it's widely diffused in Europe, there is no official EU definition yet.

According to the EU Energy Poverty European Observatory (EPOV, subsequently Energy Poverty Advisory Hub EPAH[9]), "*energy poverty occurs when energy bills represent a high percentage of consumers' income, affecting their capacity to cover other expenses. It can also occur when consumers are forced to reduce the energy consumption of their households, and consequently, this affects their physical and mental health and well-being".* **A legislative definition has been introduced for the first time in the 2021 EED recast proposal** which frames energy poverty as "*a household's lack of access to essential energy services that underpin a decent standard of living and health, including adequate warmth, cooling, lighting, and energy to power appliances, in the relevant national context, existing social policy and other relevant policies*". Overall, Energy poverty is a multi-dimensional phenomenon, caused by a combination of low-income, high-energy expenses, and poor energy efficiency in buildings. Therefore, **several EU initiatives and laws have been addressing this issue** in the context of climate policies: Renovation Wave, EED, EPBD, REpowerEU and Social Climate Fund are, among others, the once tackling both renovation and energy poverty (as detailed in Chapter 1) to ensure a fair transition (European Parliamentary Research Service, 2022).

Data collection and monitoring at both national and aggregated level are, therefore, necessary to offer insights into the full scale of the problem which is the basis for evidence-based and more effective policy actions. Since, energy poverty is a complex and context-dependent concept, it cannot be easily captured by a single indicator. It varies across different cultures, time periods, and locations, leading to the application of multiple parameters. For this reason, EPOV produced a 2020 methodology guidebook (Thema and Vondung, 2020), to **quantify energy poverty across the EU by using and combining two measurement methods**:

1. **Expenditure-based approach**, that estimates the extent of domestic energy deprivation by examining the energy costs faced by households in relation to absolute or relative thresholds.

2. **Consensual approach,** that relies on self-reported assessments of indoor housing conditions and the ability to meet basic society-dependent necessities.

[9] The Energy Poverty Advisory Hub (EPAH) is the leading EU initiative aiming to eradicate energy poverty and accelerate the just energy transition of European local governments. It offers publications, training, assistance for committed authorities and stakeholders.

A pertinent literature screening, combined with data availability at European level, resulted in the identification of a set of four primary indicators:

1. High share of energy expenditure in income (2M) – part of population with share of energy expenditure, compared to disposable income, above twice the national median (source: HBS[10]). The aim is to identify when consumption of basic energy services represents an overproportionate financial burden on households in consideration of their disposable income.

2. Low share of energy expenditure (M/2) – part of population whose absolute energy expenditure is below half the national median (source: HBS). The goal is to capture relative underconsumption of basic energy services due to lacking financial means.

3**. Inability to keep home adequately warm** – based on self-reported thermal discomfort due to financial unaffordability (source: EU-SILC[11]).

4. **Arrears on utility bills** – based on households' self-reported inability to pay utility bills (heating, electricity, gas, water, etc.) on time in the last 12 months (source: EU-SILC).

If consensual-based indicators provide a pretty accurate and updated snapshot of energy poverty throughout the EU, expenditure-based ones lack of harmonized datasets and can contain biased results. For instance, beside merely statistical considerations, M/2 can partially fail in capture underconsumption since, in some countries, energy expenditures are part of the rent or covered by the State; furthermore, reduced bills can also reflect high energy efficiency of inhabited buildings. 2M, instead, associate energy poverty to the relation between expenditure and disposable income, in comparison to the average. Due to this, low-income households that underconsume energy services may not be captured by this measure, while high-income households seem to be energy poor because they have proportionally high energy expenditure.

For these reasons, **only consensual-based indicators will be reported and further broke down according to income deciles; tenure status** (owner, rented at market rate, reduced/free rent); **urbanization density and dwelling type** (detached, semi-detached/terraced, multi-family, other).

Based on Eurostat dataset, about **36million people in the EU (8% of the population) were unable to keep their home adequately warm in 2020**. As pictured in **Figure 5** , the situation varied among EU Member States. The largest share of people reporting this issue were observed in Bulgaria (27%), followed by Lithuania (23%), Cyprus (21%), Portugal and Greece (both with 17%). In contrast, the lowest shares, were recorded in Austria, Finland, Czechia, and the Netherlands (all around 2%). Moreover, **6,5% of the EU population had arrears on their utility bills**, meaning that they have been unable to pay heating, electricity, gas and water on time, due to financial difficulties (EU Energy Poverty Observatory, 2020).

Going more deeply into the segmentation analysis, four considerations can be made:

- There is an inverse relationship between the **income decile** that a household belongs to, and the average rate of energy poverty within the group, even if energy poverty and income poverty do not fully overlap.
- Energy poverty seems to be equally split between **urban** (densely populated) and **rural** (thinly populated) **areas**.

[10] Household Budget Surveys (HBS): National consumption expenditure surveys that are used to compile weights for Consumer Price Indices. See: https://ec.europa.eu/eurostat/web/microdata/household-budget-survey

[11] EU Statistics on Income and Living Conditions (EU-SILC): A widely used pan-EU survey of income distribution and social exclusion See: https://ec.europa.eu/eurostat/web/microdata/european-union-statistics-on-income-and-living-conditions

- The categorization by tenure shows that households living in **free or reduced rate rental properties**, which include social housing, face the highest levels of energy poverty. The rates are the second highest among private renters. When considering both categories of tenants more than a fifth of them experience energy poverty. In comparison, owner occupiers have the lowest average energy poverty rates, phenomenon that may be partly attributed to higher energy efficiency opportunities and lower burden of other housing-related expenses on income.
- Finally, energy poverty is above average (up to 9%) among households living in apartments with respect to those inhabiting detached and semi-detached properties.

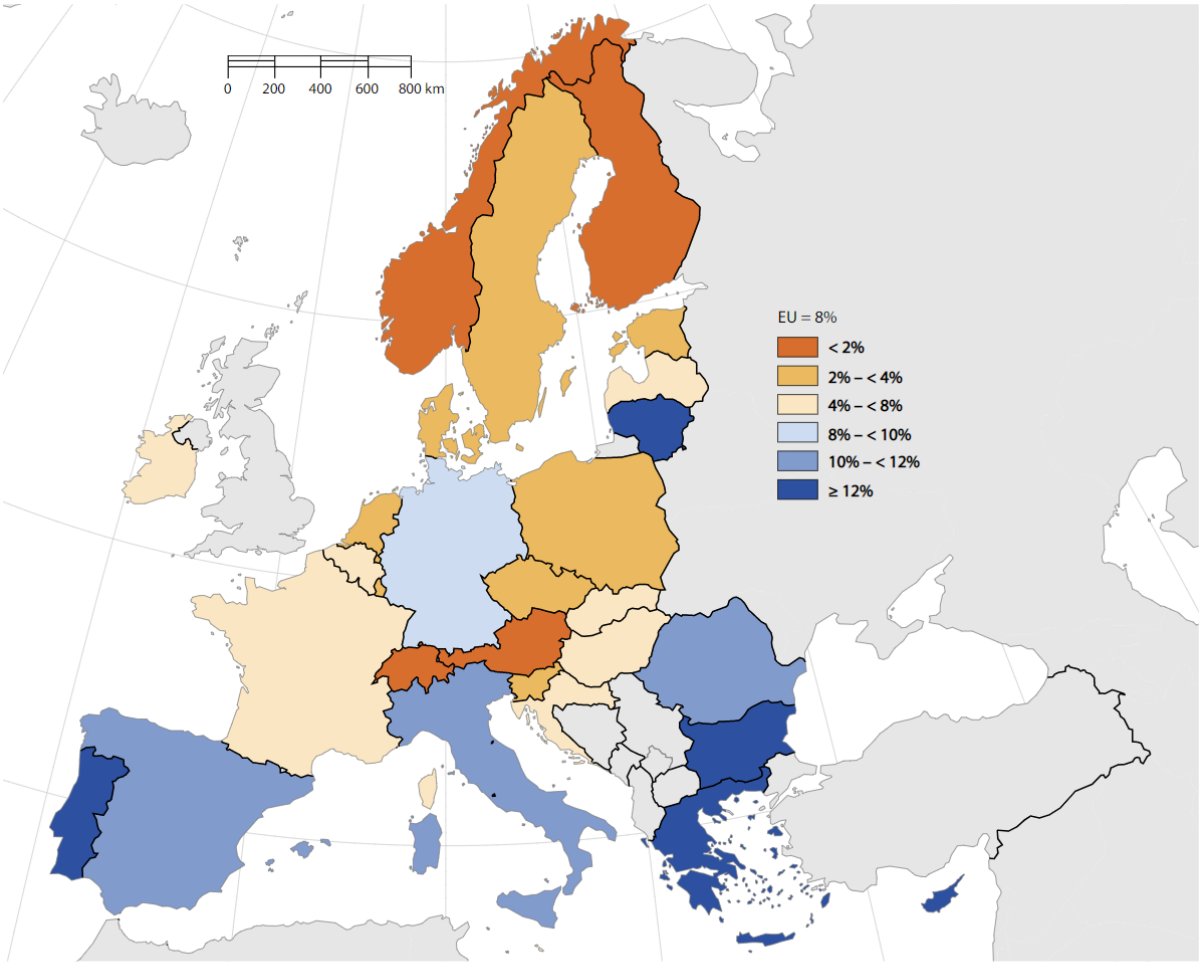


Figure 5 *Percentage of people in EU Countries unable to keep their home adequately warm in 2020. Source: Eurostat ilc_mdes01*

Overall data report quite high shares of energy poor households, burdened with significant costs for fuel, heating, and electricity. Price increases, started in 2021, were due to post-pandemic economic recovery, heightened demand, and low gas storage levels in Europe, which got even worst because of the energy supply crisis resulting from Russia's war on Ukraine. Indeed, analysis conducted by the European Commission reveal unprecedented levels of both gas and electricity bills in 2022. Beside this limited historical period, the volatile energy market prices, coupled with various socioeconomic factors and challenges will always contribute to energy poverty, unless long-term strategies and structural measures are implemented. Indeed, energy poverty has also detrimental effects on health, well-being, social inclusion, and overall quality of life. Indeed,

individuals impacted by this situation endure inadequate comfort and sanitary conditions, including unsuitable indoor temperatures, insufficient air quality, and exposure to harmful substances, which can lead to decreased productivity, physical disorders, and higher mortality rates. Energy poor households also face significant psychological stress due to unaffordable energy bills. The issue clearly extends beyond the energy sector and encompasses various policy areas, demanding coordinated efforts by multiple actors.

2.3 Social housing as an impactful share of the whole residential target

As attested by the tenure categorization of energy poverty (see 2.2), available evidence indicates that vulnerable households encounter significant difficulties when it comes to managing their homes, which are typically the least energy efficient. This means that the cost of reaching renovation standards ends to be highest for those with the least, for those low-income families that can hardly bear ordinary expenses (Portal, Kompatscher and Clark-Foulquier, 2021).

In this field, **social housing offers unique opportunities to address both energy efficiency and social inclusion ensuring a fair, inclusive and sustainable transition**. For better understanding renovation opportunities and challenges, an overview of such peculiar residential stock is provided, in terms of historical background and main categorization.

Housing started to be considered a social challenge after the industrial revolution when the massive urbanisation process caused sanitary problems and overcrowds. However, the first social housing initiatives came from private companies or charitable institutions with no State responsibility on the manner. Gradually, the provision of adequate housing to disadvantaged groups acquired public interest, as an essential step for national economic development and social peace. Only after the two World Wars, with the housing shortage and the need for massive reconstruction, social housing became a national governments' task: many dwellings in high-rise complexes were built for workers and middle classes through prefabricated concrete panels able to keep costs down and accelerate the production process.

In **Western Europe**, during the '70s and '80s, in a context characterized by oil crisis and growing unemployment, however, hosing policies increased their market-orientation focusing the reduced public expenditure only on the so-called vulnerable groups, from an economic or personal point of view. In some countries, such as the United Kingdom and the Netherlands, these policies implied the privatisation of the public housing stock through the creation of specific private not-for-profit organisations: the Housing Associations. **In Eastern Europe**, instead, the shift from state-owned rental to private-owned housing occurred in the early 1990s with the fall of communism. Due to this drastic change, unsupported by a proper regulation framework, many households had no economic means to maintain the houses they bought at a symbolic price, causing a severe degradation of the building stock.

Beside the macro differentiation between the Western and Eastern Europe approach, "social housing" lacks a common definition, since it depends on national legal, financial and institutional mechanisms, making it difficult to provide comprehensive comparisons. However, the main mission is similarly shared across EU Member States, and it has been identified as **the provision of decent and affordable dwellings, according to specific allocation criteria, to satisfy the housing needs of those households who are socio-economically disadvantaged or vulnerable groups, since they can't be met by the open market.** Due to the role that housing plays in individuals' lives, the benefiting households are strongly involved in the management of the service and in the relationship with the provider, compared to other services such as health and transport.

Overall, what diversify social housing across Member states can be classified according to 5 points of view (Czischke and Pittini, 2007; Pittini and Laino, 2012):

1. **Type of governance** which depends on the operators' categories that are allowed to provide social housing. Despite the uniqueness of the institutional framework in each country, usually responsibilities are shared between central or local governments, public companies, co-operatives, not-for-profit associations, and private organizations or investors with not all Member States reporting all types of governance. However, it should be noted that, in most cases, the sector privatization is still supported by government subsidies and financing housing programming, properly regulated.
   According to the governance schemes, renovation interventions can be easily dealt by signing private contracts or they must go through public procurement procedures.

2. **Forms of social tenures** that consist in the different modalities through which inhabitants can get the right to use the assigned affordable housing. The most common forms are rental housing, affordable ownership, cooperative housing, shared ownership. In rental housing the tenant has no property of the house, so he pays a monthly fee to the owner to be legally allowed to live in it. In case of ownership, the household has the opportunity to purchase the full equity (outright or through a mortgage loan) becoming the owner of the dwelling. In the countries in which cooperatives have a prominent role, cooperative housing can be defined as a dwelling for (subsidized/non-profit) rent or for ownership where the resident is entitled to live after buying a share of the cooperative itself. In the case of ownership, occupants own a proportion of the equity in their dwellings but usually are not able to purchase its totality. Finally, shared ownership is a form of social tenure intended to facilitate home ownership through the partial purchase of dwelling from the State or a housing association, with the option to fully purchase it at a later time.
   Depending on the social tenure, the renovation process can encounter more or less obstacles, especially in properties with multiple owners and multi-decisional challenges.

3. **Allocation criteria** that regard the policy framework and national approach with respect to the provision of social housing. Two are the macro-models, called universalistic and targeted which can be distinguished in the European Union. The universalistic approach, stems from a particular conception of social welfare which sees housing as public utility and responsibility so there is the commitment to provide the whole population with decent accommodation at affordable price, regulating the market through rent control. Overall, universalistic countries show a higher proportion of rental housing than homeownership, with social rental dominating the private one. The allocation comes through waiting lists with or without priority criteria, reserving vacancies for people with urgent housing needs, and trying to ensure, where possible social mixes to prevent spatial segregation. Rents are cost-based with rent-guarantees and allowances for disadvantaged households.
   The targeted approach, on the other hand, assumes that housing objectives can be met predominantly by the market (through the law of supply and demand). Social housing is, then,

designated only to those households for whom the market is unable to deliver decent dwellings at affordable prices. Overall, the targeted model records a much stronger share of homeownership than the universalistic approach and it is made by two sub-types: the generalist one which allocates houses according to income ceilings mainly (workers or middle-income groups), while the residual one focused on housing provision for the most vulnerable categories (unemployed, disabled, elderly, lone parents, etc.). Furthermore, generalist sub-type allocates housing on the basis of a specific set of rules and priority criteria with rents having a fixed ceiling (cost-based) partially covered by income-based allowances. The residual one, instead, usually relies on the direct allocation of housing by the local authorities based on need, with rents being either cost-based or income-based.
Based on the allocation criteria, people accessing social housing can include low to medium income beneficiaries. As a consequence, the provider might have more or less owned finance, derived from collected rents, to be invested in renovation and refurbishment measures.

4. **Size of the sector** which is illustrated by the share of social rental housing stock with respect to the total housing stock in the country. It's possible to distinguish three main groups, having a share below 10%, between 10% and 20% and above 20% which confers to social housing a different representativeness in terms of policies and market relevance within the whole residential sector, regardless of the allocation criteria. It's worth remembering that a portion of social housing is usually sold to households for ownership, even if the majority is rented. However, owned social dwellings are difficult to be statistically identified and, besides, they are no more managed by social housing providers, becoming fully-fledged private stocks to be approached as such for their renovation. For these reasons, the size of social housing potentially in need for retrofit interventions is calculated considering social rental stock only.

5. **Financing channels** that in most countries are the combination of different sources, including private, public, and internal ones. The former is mainly banking loans and bond issues, while the latter are housing organization funds, and contributions from tenants. Support from the public sector can take various forms: non-repayable grants, public loans from special public credit institutions, interest rates subsidies and government backed guarantees (in case of private loans). Furthermore, in cases where social housing is provided directly by local authorities, it makes a difference whether the financial burden lies entirely on the municipal budget or there is complementary funding, through transfers from the central budget or other specific schemes. Public subsidies can also help demand through housing benefits that contribute directly to pay a portion of the rent. Even when asking for private banks loans, a key element for the sustainability of any financing model for social housing is the existence of a system of intermediation, which makes the link between the market and the providers, under an obligation to provide funding at reasonable prices. In addition, tax privileges for social housing providers can be consider as well, since they do impact the overall financing costs even if they do not strictly fall under the category of "financing". Tax privileges include a variety of exemptions or deductions to providers, such as depreciation allowances, reduced sales and property taxes, exemptions from capital gains tax, and reduced VAT rate.
Moving more specifically to renovation, mature housing organizations can leverage their reserves and surplus (coming from rents collection and not spent for ordinary running costs) to invest in retrofit. Money raised may be also pooled to support weaker providers, as it's the case of revolving funds, which are set up for specified purposes by their members, with the provision that repayments (interests included) to the fund may be used again for the same purposes. The selective sale of part of the stock has become another key tool for generating extra resources for the improvement of the remaining stock. However, if on one hand it satisfies aspirations of sitting tenants, on the other, it must be properly regulated not to excessively reduce the overall availability. Renovations are also financed via subsidies or soft loans, both conditioned to the attainment of specific levels of energy

efficiency. In general, combining different sources of private funding with an important public support and a contribution of tenants remain the most widespread business model.
The rent increase, though, needs the agreement of the tenants in most of the cases. On the contrary, in almost none of the countries, market finance in the form of green bonds plays an important role, since housing providers need a more stable framework to mitigate their financial risk and the sector has still low rate of return.
Overall, the relative contribution of the aforementioned elements relies on numerous interconnected factors (including the ability of owners to secure borrowing in the market, the level of accumulated capital gains within the housing stock, regulatory frameworks and the degree of government commitment), and it affects the available liquidity to invest in renovation.

These different conceptions and forms of social housing respond to different cultural traditions, historical events, and policy goals, to adjust to changing conditions and requests. However, there are some recurring challenges such as affordability (to make homes accessible for all), availability (of enough housing to cater for increasing demand) and sustainability (in terms of energy and resources used in new and existing buildings) of social dwellings, which affect all Member States, even though with different urgency and priority.

The **rehabilitation and renovation of existing stock** tackles a bit of all three matters since it contributes to lower energy bills (affordability), replace on the social market buildings that were no more in condition to be rented (availability) and lower GHG emissions (sustainability).
Renovation is a priority particularly in countries where social housing was part of massive construction programs dating back to the post-World War II period. Usually, considerable investment is required to upgrade these estates, due to long-expired lifecycles aggravated by poor maintenance over time. The relevance of this manner has been recently increased because of its strict relationship with energy-efficiency and environmental-friendly policies, being nowadays the key areas where (social) housing is eligible for EU Structural funding, also given the growth-enhancing role recognized to construction and renovation works in years of recovery from economic crisis (Housing Europe, 2018).
Furthermore, **renovation is also linked with urban regeneration** as one of the ways to fight social decline. In this sense, it is crucial for achieving environmentally and socially sustainable communities. Indeed, social segregation is a widespread trend common to most European countries and it has historical roots: affordable estates were built in the 1950's-1970's to house the working classes at a time of full employment, turning into areas with high concentrations of retired people and unemployed youth in the post-industrial society. Over the last decades, with privatization of social housing and consequent residualisation to low-income groups the stigmatization of these areas has worsened the exclusion which affects residents living there. Thus, it is increasingly evident that, to prevent spatial segregation, it's necessary to have a broad-based social rental sector with a variety of resident profiles. To apply this principle to existing social housing neighbourhoods, they first need to become attractive places to live, which satisfy expectation of a variety of households: making renovation affordable is, then, the key question for social housing providers, seeking socially mixed areas beside the sole energy efficiency purpose. Counteracting urban and social decline within an aged and poor-quality stock requires an integrated approach which brings together a range of stakeholders such as local authorities, community representatives, and other local service providers, supported by public participation. In this sense, social housing providers have a key role to play, which implies the diversification of their activities to complement their core task with building facility management and social services provision, through partnerships and cooperation in programs of urban regeneration. **Renovation and rehabilitation applied to affordable housing are, then, the most obvious examples of how environment and social justice considerations can be combined** (Housing Europe, 2018) .

In this context, from the European Green Deal to the Energy Efficiency Directive, many are the legislative documents which underline the urgency to prioritize the implementation of energy efficiency measures for vulnerable households, giving precedence to social housing renovation, due to its direct impact in alleviating energy poverty. Before the pandemic, social, cooperative and public housing providers intended to spend € 35 bn per year on the development of new homes and around € 23 bn for renovation and maintenance activities - upgrading about 400.000 housing units every year. **In order to renovate the entire social, cooperative and public housing stock in Europe by 2050 to at least level B or A the number should be increased by at least 200.000 per year** (Housing Europe, 2023). However, a whole series of economic, technical, legislative, social and organizational barriers makes the social housing stock still resistant to change. Together with the promotion of energy efficient consumption habits and behavioural change, there is the strong need to address the split incentive dilemma. It arises when the party accountable for covering energy expenses (the tenant) differs from the one responsible for making capital investments decisions (the landlord or building owner). In such situations, the landlord may lack motivation to implement essential improvements to building services because the advantages derived from the resulting energy savings primarily benefit the tenant. To overcome this and other barriers, the various mechanisms to finance it are determining factors, but current policies frequently fall short in assisting those who are most in need, due to insufficient allocation of resource, subsidies programs and clear operative plans. It is, also, crucial that both the cost of financing and renovation are brought down, so that the right mix between private finance, public support and own capital can be found by social housing providers according to their national contexts.

CHAPTER THREE
Industrialized Deep Renovation for an urgent building energy transition

As it emerged by the European Renovation Wave strategy and legislation, **deep renovation is a policy goal of the EU and its Member States**. However, even as if today's state-of-art construction technologies could reduce the energy consumption of a building by more than 75%, the most diffused retrofits often achieve energy savings in the range of 20% to 30% (GBPN, 2013). Indeed, the renovation rate for deep interventions is only around 0,2%, while the annual weighted renovation rate (including light, medium and deep ones) reaches the 1,0%. So far only about 12% of the residential building stock has been renovated to meet the targets, while, to achieve climate neutrality by 2050, the renovation rate should increase to 3% with deep retrofits being the 70% of the total (Zangheri *et al.*, 2021).

These numbers show that some **highly efficient building solutions are readily available but deep renovations are not yet standard practice**. Indeed, they are at a very early stage of market uptake as confirmed by the confusion in their classification and the lack of a proper definition, within the broader picture of a construction sector that is one of the least innovative in the EU.

The scale of renovation needed in terms of number of buildings, is clearly much greater than the one happening anywhere in the world. Only the industrialization of the production can go in the direction of the speed up of the retrofit process, having the potential to considerably accelerate intervention to a significant share of stock (BPIE, 2022). However, **industrialized deep renovation (IDR)** is rarely mentioned as a unified concept, especially from a regulatory point of view. A common understanding of its proven advantages, compared to traditional retrofits, should occur before it can become a policy standard.

3.1 A definition that is slowly taking shape

To better understand what Industrialized Deep Renovation exactly stands for, it's worth analysing the two aspects separately since the former refers to the way the construction process is carried out, while the latter indicates the target level of performances to be reached, regardless of the building technologies adopted.

A. What is deep renovation?

The Energy Performance of Buildings directive 2010/31/EU has been one of the first attempts to classify major renovation as: "*a set of interventions fulfilling one of the following conditions:*

- *either more than 25% of the surface of the building envelope undergoes renovation*
- *or the total cost of the renovation of the building envelope or the technical building systems is higher than 25% of the overall value of the building*" (European Commission, 2010) .

Later, the Energy Efficiency Directive 2012/27/EU, in the preliminary considerations explained the concept of deep renovation as a "*refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels, leading to a very high energy performance*" (European Commission, 2012).

While the **EPDB classification draws the attention only on the minimum amount of needed works** in terms of renovated surface or retrofit cost, without mentioning the performances to be achieved to contribute to the EU energy efficiency goals, the **EED definition focuses on requiring a significant reduction of the building final energy consumption**, although being still qualitative.

For this reason, throughout the years, in several reports and studies the European Commission felt the need of a clear common understanding of what deep renovation means, providing specific definitions (European Commission DG Energy, 2019) for different renovation depths related to the non-renewable primary energy savings achieved in a specific calendar year:

- Below threshold ($x < 3\%$ savings)
- Light renovations ($3\% \leq x \leq 30\%$ savings)
- Medium renovations ($30\% < x \leq 60\%$ savings)
- **Deep renovations ($x > 60\%$ savings).**

As opposed to the EPDB directive, this classification focuses on the primary energy savings achieved compared to the primary energy level of the building in the calendar year before the renovation (greater than 60% for deep renovations), without mentioning a specific minimum number of measures to be covered. The attention, then, definitely shifted to energy performance achievements leaving freedom on the type of building and technical interventions to put in place.

In the same years the European Union adopted the above-mentioned directives, the building and energy research institutes started to take an interest in deep renovations, coming up with other specific definitions, among which it's worth mentioning two:

- Renovate Europe (a campaign launched in 2011 to reduce the energy demand of the EU building stock by 80% by 2050 through legislation and ambitious renovation programs) stated that "*deep renovation can achieve a reduction in energy consumption of between 60% and 90%, for the majority of Europe's buildings. When this building renovation takes place, all available energy saving technologies must be incorporated*" (RenovateEurope, 2013).
- The Rocky Mountain Institute (an independent American non-profit organization founded in 1982 to decarbonize energy systems through rapid, market-based change and address the climate crisis) defined "*deep energy retrofits as a whole-building analysis and construction process that achieves much larger energy cost savings— sometimes over 50% reduction—than those of conventional, simple retrofits and fundamentally enhances the building value*" (Rocky Mountain Institute, 2012).

Starting from the cited definitions, the Global Buildings Performance Network (GBPN) followed a tiered research approach, (made of two webinars and one online questionnaire) to clarify and harmonize the concept of Deep Renovation (GBPN, 2013). The group was composed by 30 international experts active mainly in EU, where the term "deep renovation" is widely adopted, and US where "deep retrofit" is more common. However, for the purposes of this thesis, "renovation", "retrofit" and "refurbishment" will be used as synonyms. According to the results of the GBPN process, the following conclusions have been drawn:

- **targets on deep renovation should be set both in relative and absolute terms**. However, they both require further specifications on the building type, the energy class, and the location. Indeed, relative targets depend on the initial building's health condition and age, while the absolute ones should change according to the climate zone of belonging.
- **CO2 emissions reduction targets can be omitted** even if they're the final objective, since they are strictly linked to the decrease in the energy consumed by the building stock.
- **Primary and final energy targets should be explicated**, to encourage savings on both energy generation and building operations. Priority is given to a clear primary savings goal because it's directly linked to the total emissions.
- In the European Union the most diffused and validated deep renovation definition sets the energy reductions equal to 75% or more compared to the status of the existing building before the retrofit. While the primary energy consumption after renovation should be less than 60 kWh/m2 /yr.

Finally, in the draft of the **recast EPBD** (European Parliament, 2023a), wanted by the 2021 Fit for 55 package, **deep renovation is introduced**, for the first time, among the directive's definitions, in Article 2: *"deep renovation' means a renovation in line with the energy efficiency first principle*[12] *and efforts to reduce whole life-cycle greenhouse gas emissions generated during the renovation, which focuses on essential building items, such as wall insulation, roof insulation, low floor insulation, replacement of external joinery, ventilation and heating or heating systems and treatment of thermal bridges, to ensure the necessary comfort of the occupants in summer and winter or a renovation:*

- *resulting in a reduction of at least 60 % primary energy demand for worst-performing buildings for which it is technically and economically not feasible to achieve a zero-emission building standard,*
- *and which transforms a building or building unit: (a) before 1 January 2027, into a nearly zero-energy building; (b) from 1 January 2027, into a zero-emission building".*

Also, the concept of **staged deep renovation** got its own definition (European Parliament, 2023a), meaning "*a deep renovation carried out in a maximum number of steps, following the steps set out in a renovation passport in accordance with Article 10, which may include the use of energy performance contracts".*

With this new characterization, also the EPBD shifted the focus to energy performance achievements, setting 60% as minimum primary energy consumption reduction to consider a renovation as "deep". However, compared to previous definitions, many more elements are added:

- First, whenever it's possible, retrofit interventions (and not only new buildings) must reach **nearly zero-energy levels**, before 2027, and zero-emission ones after 2027, in line with other proposals included in the revised EPBD (see paragraph 1.2).
- Furthermore, it mentions that renovation should address both the **whole envelope** (façade, roofs, joinery, and all thermal bridges) and **technical systems** (such as heating and ventilation). However, no specific reference is made to the exploitation of renewable sources, even if nearly zero-energy performances, by definition, cannot be reached without their implementation.
- Attention is also given to **occupants' comfort**, recognizing, by implication, the potential increase in quality of life attributable to deep renovation.
- Last but not least, it tackles for the first time, the way the retrofit process should be carried out underlining the need to **keep under control, not only the final results** (in terms of reduced energy consumptions) **but also the GHG emissions generated during the interventions** with a whole building life-cycle perspective.

B. What is industrialized renovation?

Therefore, moving from the performances and savings to be achieved within each deep retrofit, to the way it should be carried out, **Industrialized renovation** acquires significant relevance. It refers to a new approach based on **offsite construction methods**: the production of retrofit solutions and components is moved away from the jobsite to a controlled factory environment, at an industrial scale. Onsite operations are, then, limited to partial assembly and installation, taking advantage of efficiencies from manufacturing and standardisation. There are different levels of offsite construction, from component standardization and assembly to completed volumetric modules. Furthermore, it is not a mutually exclusive alternative to traditional methods since it refers to a spectrum of applications that are implemented to varying degrees according to the characteristics of the building to be constructed or renovated.

[12] Efficiency First means giving energy efficiency a fair chance in the models and impact assessments that policymakers use to make decisions, strengthening those laws that already target efficiency, and integrating it into all other Energy Union policies.

Industrial prefabrication is nowadays gaining traction worldwide as a viable approach, used largely for new construction, with limited applications to renovation due to higher standardization challenges. Here are a few countries where offsite new construction is more prevalent, each of them with a specific terminology (BPIE, 2022):

- **United Kingdom** has been at the forefront of offsite construction adoption. The government has actively promoted "Modern Methods of Construction (MMC)" to address housing shortages and improve construction efficiency. The UK has seen the development of numerous offsite manufacturing facilities and modular construction projects.
- **Sweden** has a long history of using "industrialized construction" methods. The country has embraced offsite building systems and has achieved significant success in producing high-quality modular buildings. The Swedish government has provided incentives and support for offsite construction projects, leading to its widespread use.
- **Japan** has been using "prefabricated housing" techniques for many years, driven by factors such as limited space, earthquake resilience, and labour shortages. The country has developed advanced modular construction systems and is known for its efficient production processes and high-quality offsite buildings.
- **China** has rapidly embraced "industrialized construction" due to its ability to meet the country's massive demand for housing and infrastructure projects. Prefabricated building techniques are being widely used, especially in high-rise residential construction.
- **Australia** is another country in which "offsite manufacturing" is gaining momentum, primarily driven by the need for faster and more sustainable construction methods. The Australian government has supported the use of prefabrication through funding programs and initiatives. The adoption of offsite construction in Australia is particularly notable in the residential and education sectors.
- **United States and Canada** have been slower in adopting "modular construction" compared to some other countries, but there has been a recent surge in interest and investment. The use of prefabrication is growing, particularly in urban areas where there is a need for faster and more efficient construction methods.

In terms of definition, while "industrialized", "offsite", "prefabricated", "modular" can be considered synonymous, **"modern method of construction (MMC)"** refers to a slightly different and broader concept born in the United Kingdom. While Sweden is the European country where prefabrication is applied the most with a development being technology driven, for the **UK government** offsite construction has recently become a strategic focus and various exemplary reports have been published. Indeed, decades of under supply have seen a housing shortage lurch into a full crisis with a serious impossibility to meet demand. To face the challenge, the Deputy Prime Minister set up the Construction Task Force, led by John Egan who, among others, wrote the famous report "Rethinking construction" (Egan, 1998). The **need to increase prefabrication in the housing sector** was discussed, drawing on experiences of manufacturing industry, to identify how to improve efficiency, reduce waste and make the sector more responsive to changing needs. More recent reports, such as "offsite manufacture for construction: building for change" (House of Lords, 2018) and "Modern Methods of construction: introducing the MMC definition framework" (MHCLG Joint Industry working group, 2019) reinforce the same ideas. The latter is particularly important since it aims at standardizing the MMC terminology to enable better access to finance, insurance and affordable housing procurement (for which bidders are required to cite the types of MMC potentially deployed). MMC is define as "*a range of approaches which spans offsite, near site and on onsite pre-manufacturing, process improvements and technology applications*". There are seven categories in the definition framework, as shown in **Figure 6** and listed below:

1. **3D primary structural systems**, referring to volumetric construction involving the production of three-dimensional units, in controlled factory environment, which are then combined on site to

create a building. The systems include structural performance and is the form of MMC that incorporates the highest level of pre-manufacture. The extent of work that is carried out to each unit can vary (form basic structure only, to internal and external finishes or services installed).

2. **2D primary structural systems**, meaning the creation of flat panels units (walls, floors, roof) and framing systems away from site that are assembled onsite to produce the final three-dimensional structure of a building. Panels can consist of a skeletal structure only (with more works do be completed onsite) or can be more complex including lining materials and insulation but also windows, doors, finishes and external claddings.
3. **Non-systemized primary structure**, referring to the use of pre-manufactured components to form part of the structure and foundation of a building (load bearing beams, columns, roof slabs, staircases, pile caps, screw piling). Each of these elements is constructed offsite but it's not part of a systemized design such as category 1 and 2, having higher onsite flexibility in their composition.
4. **Additive manufacturing**, relating to the 3D printing of components or whole elements of buildings through various materials based on digital design and manufacturing techniques. It can be both structural and non-structural, remote and site based.
5. **Non-structural assemblies and sub-assemblies**, meaning a series of different pre-manufacturing approaches that includes non-structural processes that otherwise would be delivered on site (walling systems including glazing, roofing finish cassettes, non-load mini volumetric units, such as bathroom or kitchen pods, M&E assemblies for central equipment of distribution).
6. **Traditional building product led site labor reduction/ productivity improvements**, including traditional single building products manufactured in large and pre-cut configurations with easy joints so that they are quicker, easier, and safer to install, to reduce the extent of onsite labor (internal walls systems, roof finishings, modular wiring and pipework).
7. **Site process led site labor reduction/ productivity/ assurance improvements**, encompassing the use of onsite systems and processes to drive productivity by removing unnecessary work stages, enabling better and faster installation, and improving health and safety. It comprises lean and BIM construction techniques, site encapsulation measures, standardized temporary works, digital tools (GPS, AR/VR, scanning), robotics and autonomous equipment (drones, driverless cranes).

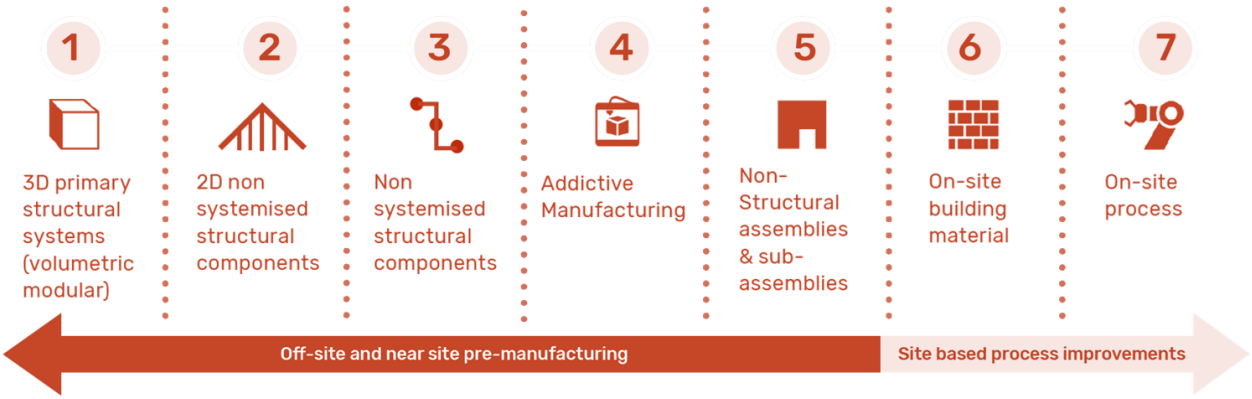


Figure 6 *Modern Methods of Construction classification. Source:* (MHCLG Joint Industry working group, 2019)

According to this classification, offsite construction is just a sub-category of **MMC** including pre-manufacturing categories only (points 1, 2, 3 and 5), in which components are realized away from the building site. To be effectively implemented, **offsite construction requires Design for Manufacture and Assembly (DfMA)** which is the process of procuring and designing a project so that a significant portion of works can be constructed in factory to be locally assembled.

Nowadays, MMC is a widely recognized and adopted categorization even outside UK, but it's mainly intended for new construction and development projects. When adapting it to renovation, structural categories (1,2,3,4) are rarely used. Two are the only exceptions: interventions where volumetric increase is planned (typically through extra floor or ground extensions) or anti-seismic adaptations are needed (extra load cannot be hanged to existing walls so the prefabricated solutions must be freestanding). In all other cases, for energy efficiency only, **the most common MMC used for renovation is category number 5, non-structural assemblies and sub-assemblies, in the form of integrated wall and roof panels** (including photovoltaic, windows and/or other technical ducks or equipment). When buildings have specific technical constraints or surface irregularities, categories 6 and 7 are also used to optimize onsite works of those portions which cannot be retrofitted using offsite components.

3.2 Main benefits and current adoption barriers

Besides the above-mentioned players, the growth and diffusion of offsite construction methods continue to expand globally as technologies keep advancing and boundary conditions get more favourable. However, especially for renovation, there is a need for further process improvement to enable the market penetration of industrially prefabricated solutions: significant innovation drivers and preconditions are required to ensure technical-economic feasibility and diffused benefits recognition.

So far, the potential benefits (such as time, safety, cost, quality, etc.) have been investigated primarily for new offsite construction (with evidence coming mainly from UK and China). Since there are no comprehensive studies on offsite retrofits and the quantitative results obtained for new prefabricated buildings are very technology-related and context-specific, available reports from Buildoffsite[13] (Krug, 2013; Building Engineering Services Association, 2015; Jansen Van Vuuren and Middleton, 2020) have been used to outline a qualitative tree diagram showing the main industrialized deep renovation benefits and their correlations (**Figure 7**). When present, in addition to advantages, challenges and preconditions will also be highlighted to give a comprehensive picture of the change of working approach that offsite requires.
The idea is to provide an exhaustive taxonomy of all possible benefits and their reciprocal links, so that, when enough case studies are available it will be easier to assign quantitative inputs and functions to get to economic outputs (savings to be considered in the business plan). The identified metrics have been grouped in three categories:

1. **Direct advantages** which are strictly related to a deep industrialized retrofit and differentiate it from a light and traditional intervention. The time frame considered is just the short term, from the design stage till onsite renovation works.
2. **Indirect benefits** that are related to broader project impacts, linked to direct advantages, and leading to parameters that can be economically quantified and valorised. They take into account the whole building lifecycle and different stakeholders' categories (owner, tenants, workers, society).
3. **Economies of scale** which come into play when more than one project is involved, as long as a pipeline of similar and clustered buildings renovations is planned. These advantages can be split among solution providers, general contractors and stock owners or developers.

The last column in bold, in **Figure 7**, highlights the financial benefits which might be associated with each attribute. Indeed, economic considerations are often seen to be the most powerful ones in influencing the choice of renovation/ construction method. The builder and the owner are identified as critical parties in

[13] Buildoffsite is an industry-wide campaigning organization that promotes greater uptake of offsite techniques by UK construction. It works with its membership, government, key industry stakeholders and supply chains, to deliver permanent, positive transformation and impact, by normalizing offsite and Modern Methods of Construction. See: https://www.buildoffsite.com/

making the decision to adopt offsite techniques. In situations where the main savings all accrue to the same party the case for adopting industrialized approaches is particularly compelling.

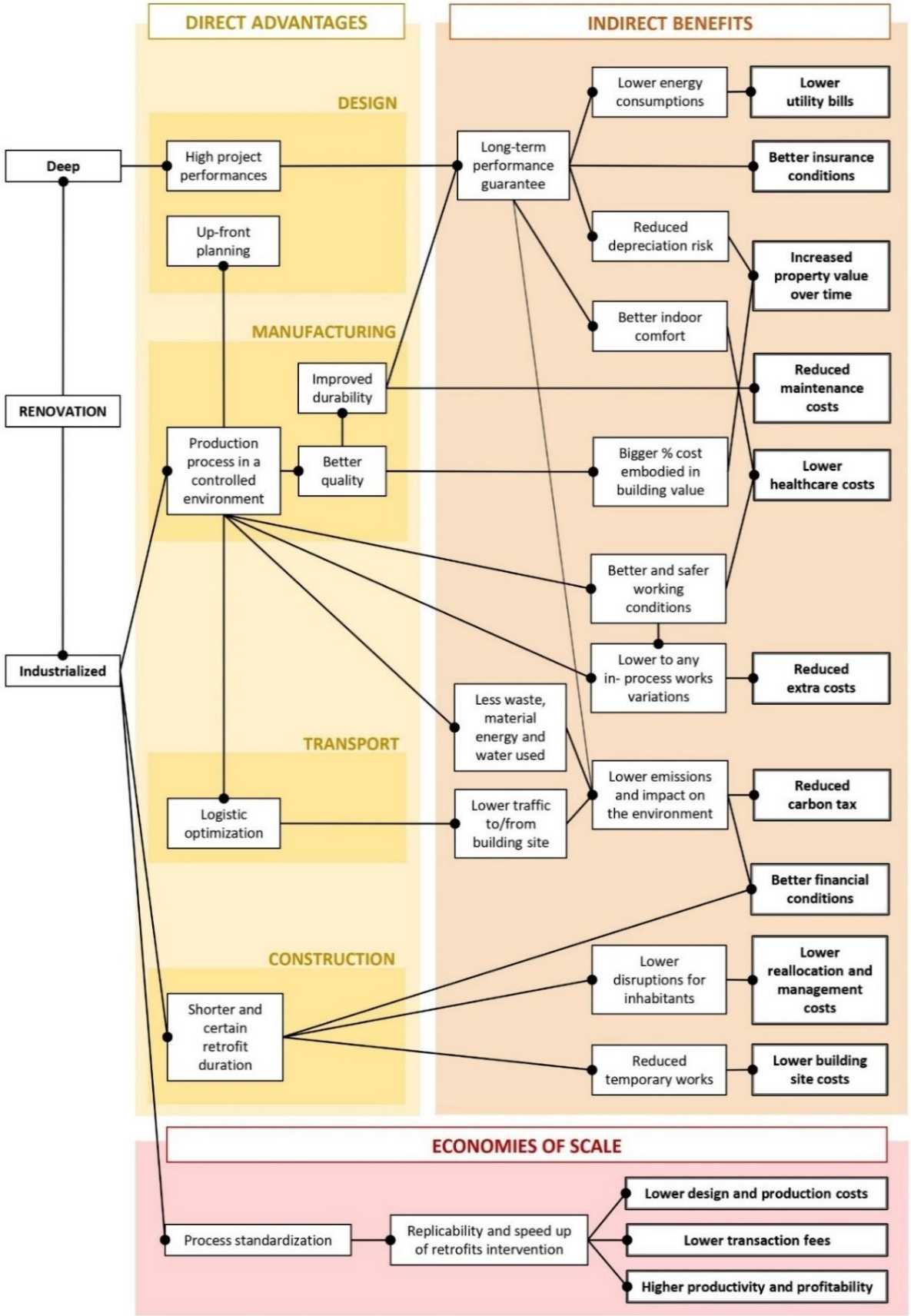


Figure 7 *Industrialized renovation benefits and their reciprocal correlations*

1. Direct advantages

Starting from the **deep renovation**, as seen in paragraph 3.1, its main characteristic lies in the intention, from the design phase, to reach **high project performances**. They are mainly related to energy efficiency (at least a planned reduction in energy demand of 60%) but they can also include anti seismic, air quality, sound insulation, daylighting improvements. Such performances, though, can be reached - on paper - even through a traditional intervention (typically an external coat insulation for walls and roof, together with the replacement of the old generation system and the installation of photovoltaic panels).

The reason to implement **industrialized renovation** lies in a list of broad advantages that, among others, allow to enhance and actually exploit the building's better performances. This requires consideration of the economics of the project as a whole, not just substituting and comparing the technical solutions cost items. First, the production of retrofit components happens in the factory, which is a controlled environment Manufacturing and assembly in offsite facilities is able to provide the benefits of **better-quality** products that fit well on site. This includes a tested airtight envelope and M&E systems/pipework that has been assembled in monitored conditions before they come anywhere near site. Due to such prefabrication, the retrofit solutions perform much closer to their ideal specification targets (with a reduced number of post-completion defects) than those which are produced and commissioned onsite. Beside the quality of construction works, also the quality of the completed asset is consequently increased, leading to **improved durability** and more reliable performance over time, which will be crucial for the characterization of indirect benefits.

However, differently from conventional interventions, offsite manufacturing processes requires more emphasis on **up-front planning** with lower design flexibility throughout the renovation phase. Advanced and coordinated planning are required to allow sufficient engagement with manufacturers. Traditional design, instead, comprises progressive development of increasing levels of detail until all components are defined and materials are specified. Accurate information on building shape and works to be done is, then, necessary for a proper DfMA. As an essential precondition, additionally to technical solutions, emphasis is needed on process innovation, since most of the coordination for industrial prefabrication happens in early stages. More digital solutions and interoperability have the potential to transform how renovations are conducted (sensors, Internet of Things - IoT, drones, 3D scanning, robotics, 3D printing and of course BIM). Currently, Building Information Modelling (BIM) for renovation is not yet widespread, being mainly limited to the design phase of larger projects, so policy support is needed for the implementation and integration of digital solutions to incentivize building decarbonization. Tools like BIM and a digital building logbook can, indeed, help create synergies between technologies, keeping all data and information in a central, easy-to-access location, which is crucial for the prefabrication phase, but it also optimize the management of the entire building lifecycle.

Moving to the transport phase, thanks to industrialization there is a significant **optimization of the logistics**. In the traditional scenario, labour and all necessary materials arrive and leave the construction site in small, medium, and large vehicles, the frequency and capacity of which depend on the daily work schedule, with limited storage possibilities. Moving a large part of the activities to the factory enables greater efficiency of the handling of construction components, as the common starting point allows the transport to be planned and the capacity of the relevant vehicles to be saturated. However, it must be considered the distance between the factory and the building site since the logistics optimization occurs when large modules are transported for relatively short routes. Otherwise, temporary factories can be rented near the site to carry out final assembly.

Finally, but most importantly, during the renovation phase, a key driver for the use of offsite construction is the **reduced time onsite, together with greater certainty in construction program** and reduced risk of delay, enabling projects to run on time to meet client requirements. It is the result of several different factors, including:

- concurrency of activities and ability to conduct preparatory site works in parallel with manufacturing of the offsite elements;
- fewer risk of rework or not having the right components available on site;
- reduced variables affecting the project schedule, such as exposure to bad weather conditions;
- Lowered variability in labour productivity and higher productivity rates happening in factories;
- less onsite staging and less equipment and facilities to be removed from the site at the end of the project.

2. Indirect benefits

Combining the high project performances, given by deep interventions, with the improved durability, ensured by industrialization, **long-term performance guarantee** is one of the key advantages of such renovations. It's, indeed, necessary to ensure the economic feasibility of the business model as it happens in the Energiesprong approach. Thanks to prefabrication, there should be no o very little distance between the performances declared in the design phase and those that occur after installation, in the operative phase of the building. This allows the construction company to guarantee that the implemented measures will perform as intended over a more extended period, compared to traditional ones (which are much more dependent on building site installation methods).

However, onsite skill set needed for both management and offsite installation workers is very different from traditional practice as the requirements include the assembly of ready-made components, the use of new materials and systems, the handling of large building modules and the need to ensure that sophisticated systems work as they should. Site works need to be carried out by a relatively small team of multi-skilled site operatives who typically develop their expertise over a series of projects. Until industrialized renovation become standard practice, ensuring long-term guarantees can be a bit risky, since there is still a part of performances that depends on onsite mounting process and availability of trained installers. Furthermore, assessing the long-term performance of deep renovation can be complex and challenging for two reasons:

- It requires monitoring and evaluating multiple parameters, such as energy consumption and indoor comfort levels over time. The variability in building types, climates, occupant behaviour, and other factors can make it difficult to establish universal performance metrics and guarantee thresholds.
- It often involves cutting-edge technologies and innovative solutions, so the availability of long-term data and benchmarks for these measures may be limited. Without sufficient historical performance data, providers may hesitate to offer guarantees on the effectiveness and durability of these solutions.

Developing standardized and reliable evaluation methods is a necessary step towards widespread adoption of long-term performance guarantees. Indeed, industrialized deep renovation industry is still evolving, and comprehensive regulations are still incomplete. Proper contractual agreements and guidelines are needed to set terms, conditions, and the maximum duration of the coverage (above 10 years). The establishment and use of an external guarantee fund could address the need for de-risking in this young market, by removing the financial risk of entering into a long-term contract for both the provider and the building owner.

Investing time and resources in setting affective and trustable long-term performance guarantees unlock a series of other benefits:

- **Lower energy consumptions** directly linked to **lower utility bills** for the renovated building inhabitants. The improvement of the energy-in-use characteristics for the whole validity of the guarantee is reflected primarily in energy savings related to reduced or absent gas usage.
  The offsite approach, due to the better finished quality (for the same design performance) allows for fewer defects, better airtightness, less gap in insulation and more efficient mechanical and electrical

systems. The industrialized renovated building, then, perform closer to predict levels than onsite assembled components, increasing the operational efficiency for a relevant period.
This aspect is particularly relevant in renovation projects, compared to new construction, since new performances, beside being compared with the one reached by a traditional intervention, are clearly improved with respect to no insulated building. Energy savings are the key element (together with other benefits) to create a sustainable business model able to return of the initial investment over time, as it is the case of Energiesprong approach. However, due to the split incentive dilemma, lower utility bills are unlikely to drive the adoption of offsite techniques by either the building owner or the building contractor (since neither of whom has a financial interest). In addition, the lack of funding opportunities and/or inability to secure finance on acceptable terms is generally one of the most cited barriers to investing in energy efficiency measures, together with the time taken for the high upfront outlay to be recouped through life cycle costs savings. A more relevant factor in driving change is the increased visibility given by higher Energy Performance Certificate (EPC) ratings. A good rating is likely to attract developers and owners with an interest in demonstrating their commitment to carbon reduction, the Green Agenda and ESG[14] criteria.

- **Better insurance conditions,** including the posthumous (or decennial) liability insurance. It is a special form of compulsory surety according to which the builder of a new or deeply renovated building is obliged to insure the purchaser/owner against any construction defects that may occur in the ten years following the date of completion of the work. Long-term performance guarantees in the building sector can potentially lower insurance costs since they provide assurance that the implemented deep renovation measures will perform as intended over an extended period. Furthermore, the emphasis on quality control helps minimize the likelihood of construction defects or performance failures. For this reason, insurance providers may view a reduction of their risk exposure, resulting in lower premiums for posthumous liability insurances.
- **Reduced risk of depreciation** of the asset since it's proved to perform better for longer. This aspect, together with **a bigger percentage of total cost embodied in the building value** (since all the costs related to reworks, errors and delays are minimized), leads to an **increase of the property value**, not only soon after the renovation but over the whole guaranteed period. Furthermore, the quality obtained in factory can also improve the component's aesthetics, since finishing processes also happen in a controlled environment with an accurate appearance monitoring. This is particularly relevant in location where landscape or historical constraints are present. Indeed, differently from the prefabrication of the '50s, the standardization of the manufacturing process allows for a better focus on the final customization, playing on different panel sizes, textures and colours. However, to guarantee architectural quality, the prefabricator must collaborate with the designer from the outset. Teamwork is essential in the kick-off phase of offsite approach to ensure that aesthetic requirements, which contribute to the building value, can be met and available options can adapt to different contexts and constraints. Besides the architectural consideration, the improved and guaranteed EPC rating is another significant addition to the building's commercial value. Such benefit, in opposition to lower utility bills, is an important driver for owners, investors and developers which are interested in selling the asset or increasing the rent after the renovation thanks to the enhanced internal performances and external appearance.
- **Better indoor comfort** which is the most subjective benefit depending on the building users' wellbeing during occupation. Using an offsite approach, which guarantees high level of performances and integrated monitoring systems, should results in better indoor comfort (preventing air pollutants, controlling the temperature, accessing daylight, etc.). The most famous index is the IEQ (Indoor Environmental Quality) which simply describes the conditions inside the building. However,

[14] Environmental, social and governance (ESG) is a framework used to assess an organization's business practices and performance on various sustainability and ethical issues. While sustainability, ethics and corporate governance are generally considered to be non-financial performance indicators, the role of an ESG program is to ensure accountability and the implementation of systems and processes to manage a company's impact.

they are not universally defined: tenants' satisfaction cannot be neglected, which means understanding initial expectations and how these evolve through the project and building use. In this sense, the tenant engagement since early renovation stages and the adoption of user-oriented design are crucial aspects in the delivery of solutions and tools that increase the indoor comfort. Installed Building Management Systems (BMS) must be user-friendly and easily governable by the inhabitants who can, therefore, improve their quality of living. Training ad sensibilization on the suggested tenants' behaviour (such as keeping the windows closed and so on) is also necessary to maximize performances and savings. On a bigger extent, especially when talking about dilapidated social housing, from improved comfort derives better health and wellbeing of the inhabitants and lower risks of diseases or disorders, meaning **lower overall healthcare costs**.

Lower emissions and impact on environment, beside the ones linked to energy consumptions during the building operative lifecycle, are also related to the manufacturing, transport, and disposal phase.
Indeed, the production process in a controlled establishment, implies:

- **Waste reduction**, which is closely link to typical industrial processes. The efficient use of resources in constantly monitored factory environments results in high quality components that are rarely defective or in need of rework, thus minimizing scrap production. The little waste produced, being in a controlled and properly organized location, can be easily fed back into the production process or recycled, as waste sorting is easier to be managed than onsite. At the end of its life, thanks to DfMA and dry construction, a large part of the building, instead of being demolished, can be disassembled leading to the reuse and recovery of part of the prefabricated components that, if built with traditional technologies, would end up in landfills. However, reuse potential is currently unlike to be a major factor in consideration during the design phase of renovation components (attention on connections and joints reversibility, integrity of dismounted elements, etc.).
- **Decrease in the quantity of material used,** in addition to the reduction of waste. The production of components in the factory allows for much more predictable processes compared to onsite construction. The quantity of material can, therefore, be calculated more accurately due to the high design efforts required by DfMA, and there is less overestimation of raw materials needed thanks to the reduction in error margins. In addition, planning all activities that require the use of the same materials in a more synergetic and closer manner allows for more optimized batch ordering across different processes. Finally, the incidence of material for the same surface area realized is lower, since production with numerically controlled machinery allows the thickness of the prefabricated components to be reduced, for the same performance obtainable on site. Industrialization also implies the minimization of the activities to be performed onsite, decreasing the risk of losing material temporarily stored waiting to be processed. Given the continuing rise in the price of building materials (exceeding 8 per cent in 2022), economic considerations can be added to sustainability, leading to savings in the renovation price and/or in the increase of builder's margin.
- **Containment of water consumption,** which is one of the most consumed resources during the entire life cycle of a building. While in the operational phase, water consumption depends mainly on the habits of the tenants, in the construction phase it can be reduced to improve the sustainability of the intervention. Approximately two-thirds are attributed to the extraction and preparation of materials, while only less than one-third is consumed on site. Possible savings come mainly from: reduction in the quantity of material for the same number of components produced, leading to a consequent reduction in the water incorporated in them during production; optimization of work and site schedules resulting in reduced water consumption associated with activities such as dust removal, vehicles and equipment washing; need for less onsite labour for shorter periods meaning a lower demand for water for sanitary facilities and temporary accommodation (which becomes especially relevant for large-scale interventions). In terms of benefit relevance, due to climate change, the water crisis is becoming an increasingly looming problem, with the construction sector responsible

for around 20% of the world's water consumption. So, even if water has not a significant cost compared to the total price of the project, its control and proper management is becoming more and more necessary to achieve sustainability targets.

- **Energy savings** that, in the manufacturing phase, are linked to the transformation of raw materials into semi-finished construction products and the production of prefabricated components. The range is highly variable because the actual energy consumption is strictly dependent on the technology and type of intervention carried out. The main parameter to be considered is the **embodied energy**[15], which is reduced due to process optimization, investments in highly efficient machinery and a higher coverage of renewable sources in the factory, with respect to temporary building sites, thus containing the environmental impact of the intervention. In fact, concentrating most of the works in the factory, lowers the energy used to power machinery, tools and site lighting. Such savings are also directly quantifiable in economic terms even if the impact on the total cost of the traditional intervention is limited. However, given the recent fluctuation and increase in gas and electricity prices, variations have become more significant and with them also the margin of savings guaranteed by an offsite intervention.

However, in doing a lifecycle assessment analysis, it is worth considering that, keeping the surface of intervention unchanged, the retrofit wall has more components than a traditional coat insulation, so benefits (water, material, waste, and energy) are lower with respect to new construction in which the entire structure is to be built and prefabrication plays a crucial role in resources optimization. In renovation, instead, advantages of such optimization are partially counterbalanced by the increased number of layers and functionalities integrated in the wall or roof panels (kg/m^2). It's, then, crucial to set the proper assumptions when calculating the **embodied carbon**[16] of industrialized renovation components to make them reasonably comparable to lighter conventional interventions (which, for example, have much higher disposal-related emissions). Overall, the environmental footprint can be improved if bio-based materials and circularity principles are introduced in the manufacturing process.

Moving to the transport phase, thanks to the logistics optimization a limited number of large vehicles concentrated in a smaller time frame is therefore necessary. The number of workers is also lower, reducing the number of cars reaching the site each day. Since, for the same load and route, many small vehicles pollute more than few large vehicles, the environmental impact attributable to offsite logistics is less than the traditional one. This **reduces the number of journeys and the road traffic to/from the construction site**, bringing additional benefits in containing noise and emissions in the proximity of the buildings to be renovated. Indeed, a significant part of the transportation is moved close to the factory, which is usually located outside urban areas, thus reducing city congestion and pollution.

Overall, lower emissions during the whole building lifecycle brings two economic benefits:

- **Reduced carbon tax**, linked with the extension of the ETS to the building sector. To date, carbon pricing has tended to apply to carbon-intensive production activities, being ineffective at influencing construction design, which is where carbon emissions are locked in for the duration of an asset's life. With the introduction of broader carbon pricing mechanisms, industrialized deep renovation approaches which minimize carbon emissions will positively impact on project costs, becoming more appealing for both builders and clients.

[15] Embodied energy is expressed in GJ/m^2 and it represents the energy involved in the entire life-cycle of a construction or renovation element (production, use, maintenance and disposal).

[16] Embodied carbon is the sum of greenhouse gas emissions released by a construction product or system during the entire life-cycle stages. It is expressed in KgCO2e, and it uses the global warming potential (GWP) to consider the different effectiveness of warming earth with respect to carbon dioxide.

- **Better financial conditions**, mainly related to green finance. It refers to financial products and services that support environmentally sustainable investments, such as industrialized deep renovations that prioritize energy efficiency improvements. It enables property owners to overcome financial barriers, making sustainable renovation more accessible and financially viable. Indeed, projects that demonstrate strong environmental performance and sustainability are often seen as less risky and more attractive to lenders. Therefore, focusing on sustainable practices unlocks improved access to capital (loans and bonds) at lower interest rates or more favourable terms, especially if recognized green building certifications, such as LEED[17], are obtained. For example, it has been proved that default rates of mortgages with good Energy Performance Certificate ratings can be up to 28% lower than those of mortgages with poor EPC ratings. In addition, regulatory bodies are increasingly implementing policies and incentives to promote sustainable practices and reduce environmental impact. These initiatives include tax incentives, grants, subsidies, and favourable regulatory frameworks for green investments.

In connection with the above-mentioned benefits, offsite **drastically reduce in-process works variations** which occurs after the construction or renovation phase has begun. In traditional interventions, design changes are the primary contributors to disruption of construction projects. Industrialization requires to bring forward most of planning and design efforts, increasing the predictability of works, thus **reducing costs overrun** due to delays, claims and extra resource management. On the other hand, offsite construction, has a lower design flexibility and consequently a limited ability to adapt to late client changes, due to the time required to start the integrated manufacturing again. If such variations are unavoidable, they have a greater adverse effect on projects with higher levels of industrialization.

Better and safer working conditions are still related to offsite manufacturing in a controlled environment. Indeed, construction sites has a series of risks intrinsically linked to the type of activity to be carried out: the use of heavy machinery, the handling of dangerous materials, operations at height. Although working conditions have improved in recent years, the construction sector still has one of the most significant accident rates (due to falls of workers from height, fall of loads on workers and loss of control while driving). In the offsite scenario, most of the activities are moved to the factory, where there are lower risks of accidents and more ergonomic working conditions, positively affecting employees' mental health. In fact, such environment has several benefits: mechanized handling operations, job rotation to avoid repetitive tasks, cleaner spaces, less exposure to hazardous substances, less crowded working environments and better care facilities.
In addition, the remaining activities that must necessarily be carried out onsite require less time and fewer operative teams, minimizing exposure to the risk of accidents. The installation of prefabricated panels, for example, is safer, due to the reduced need to work at height, which allows the use of protected lifting platforms instead of complex scaffolding systems.
On an economic level, poor occupational safety and health have major consequences for construction companies that are reflected in the end price of the renovation intervention: when accidents occur, workers suffer injuries that lead to slowdowns in the construction process with a reduction in expected productivity. This results in direct and indirect extra costs related to medical expenses, unused wages, additional administrative procedures, and increased insurance premiums. The financial benefit for society, on the other hand, is linked to **lower healthcare costs** and so the economic resources that the national health system could invest elsewhere.

[17] LEED (Leadership in Energy and Environmental Design) is the most widely used green building rating system. LEED certification provides a framework for healthy, highly efficient, and cost-saving green buildings, which offer environmental, social and governance benefits.

In addition to reducing injuries and accidents, offsite construction can significantly improve working conditions beyond purely safety aspects:

- First, working in factory is a source of stable employment with all the social and financial benefits that come with it, as opposed to the uncertainty provided by project-based calls that are tied to the start and duration of the building site.
- In the factory, it is possible to work in protected environments regardless of external weather and climate conditions. In addition, the presence of automated machinery makes it possible to assist workers in lifting and handling of heavy components.
- For employers, having a more standardized and controllable manufacturing process paves the way for continuous improvement of the technological solutions implemented, moving closer to manufacture industry's mechanisms. At the same time, workers are given more opportunities to develop qualifying skills to deal with updated machinery and more complex supply chain management.

Going back to improved durability, besides enabling long-term performance guarantee, it is strictly linked to **reduced maintenance costs.** The main economic drop comes when dealing with extraordinary maintenance (repairs and renewals) since offsite components last longer than traditional ones so, for the same lifecycle, less replacements are needed, and the likelihood of emergencies is lowered. Moving to planned ordinary maintenance, its efficiency is improved thanks to greater standardization of components with precise deadlines and clear points of reference within the supply chain (which is more integrated). Due to the high level of innovation, it's important of ensure that exhaustive information is included in the handover documentation to allow preventive maintenance to be correctly executed. On the other hand, factory finished units may be more complex and, in case of localized defaults, the replacement of the entire section might be required.

Moving to the construction phase, shorter and certain retrofit duration is also related to **better financial conditions** since the speed of the intervention confers a major advantage on the building owner/developer in the form of reduced interest expenses: works are finished earlier, incomes are collected sooner, and loans can be paid back quicker. This is surely relevant in new construction projects in which time savings are significant and revenues refers to sale or rent of additional apartments. For the renovation, instead, they mainly concern energy savings and increased rent (where possible) of existing dwellings so both economic surplus and time shrinking are lower, making the financial benefit less relevant and appealing. Furthermore, offsite panels, being more complex than a traditional energy efficiency intervention, require high upfront costs and so a bigger initial investment, translated into the need of a greater loan (meaning higher interests absolute value at the same interest rate). Also, the novelty of the process could mean higher lending rates until enough offsite interventions are realized, and the reduced risks are clearly proven. Better financial conditions are, then, dependent on various variables (e.g. debt over equity) which have to be evaluated on a case-by-case basis.

A more straightforward benefit, strictly related to the reduced time spent on site, is the **lower disruption for the inhabitants**. Indeed, every building site creates quite a few inconveniences for the neighbourhood: noise, pollution, emission of harmful substances, the sight of cranes and scaffolding, traffic congestion. In fact, since the construction site has a shorter overall duration, the problems associated with it are more concentrated and more bearable. In addition, the type of activity that remains to be carried out on site mainly concerns assembly and finishing, activities that produce less dust and disturbance than manufacturing. The disruption factor is crucial especially in cases of deep renovations or where part of the site needs to remain live during the works (schools, hospitals, prisons, etc.). Economically, it can be translated in **lower reallocation costs** (if inhabitants couldn't stay inside the building while a traditional intervention is ongoing) **and minor management costs** for the building owner. The latter are due to lower complaints of the tenants who might be reluctant to face renovation work and, thus, hamper the process. Major dissatisfaction can be avoided if owner and occupants have been sufficiently informed of the retrofit plan and the advantages of an

industrialized approach. So, once again, sensibilization and tenant engagement is a key precondition for innovative prefabricated methods to be appreciated. From a broader point of view, offsite construction can reduce the extent of loss of revenues of business located next to the building site and the loss of amenity, if the use of some public facilities is affected during the works.

Finally, a clear benefit linked to offsite and fast renovation techniques is the **reduced temporary works needed,** which lead to **lower building site costs.** The main source of saving is the limited or non-existent use of scaffoldings and the consequent low taxes for the use of public ground, but also the fewer tools and equipment which needs to be rented. Furthermore, due to less labour and activities to be done onsite, construction supervision, work management and security coordination efforts are significantly contained. On the contrary, the building site location and position must allow the room for manoeuvre of heavy trucks and the handling of wide panels, otherwise traditional retrofit operations are required.

3. Economies of scale

The adoption of offsite techniques has diffused environmental, social and financial benefits also when considering an isolated renovation project. However, the biggest advantages and improvements come into play when economies of scale can take hold, meaning the cost advantages suppliers experience when production increases and becomes efficient, as expenses can be spread over a larger amount of finished elements. Industrialization is a key driver for **standardization construction processes**. Indeed, the optimization and digitalization of manufacturing, which can happen only in highly technological factories, foster the **replicability and speed up of interventions**. This is particularly true for new construction developments where modularity can be implemented without particular constraints. In the renovation field, each project is dependent on the actual building characteristics and there is less margin for standardization. However, the scalability to portfolio of projects is still possible, providing greater value to the client thanks to incremental improvements coming from lesson learnt. This affect both the **design and production phases' efficiency, lowering the related costs** and moving the construction industry from a project-oriented to a product-oriented approach. Also, **transaction fees are contained** because the supply chain is much more integrated, and all purchase and procurement operations undergo less intermediate steps so they can be better coordinated and merged among different orders.

Taking into account all these considerations, with the diffusion of deep industrialized renovation intervention the overall benefit will be the **increase in the productivity and profitability** of the industry, which are salient issues in construction reporting minimal improvement over the last decades. Productivity is defined as the amount of output per unit of input, considering labour, material, capital involved, and it is strongly affected by the workplace management and logistics. In a sector in which, the availability of employees is limited, offsite can change labour requirements, making the job more attractive while allowing a numerically smaller workforce to renovate houses faster than traditional rates. The possibility of doubling the pace with the same internal resources employed, clearly generates a greater yearly profitability for builders.

However, **stability in the supply chain and manufacturing facilities** are essential to improve efficiency and increase scale. Large volumes are required to achieve the benefits of industrial prefabrication, causing a dilemma for solution providers who are unsure whether they can tap into reliable demand pipelines. Programmatic working for social housing companies or other larger building owners has large potential to drive such demand bundling, because it involves switching from single renovation projects to multi-year planning strategies. This allows sufficient predictability that enable the profitable implementation production lines in factory environments. In addition to volume aggregation, prefabrication facilities require large upfront investment, being a crucial area for support not only from government, but also financial institutions and investors. Innovative policy support and funding programs focused on the intermediate stage between

pilot and mass market could ease the market development. Such incentives should target both the supply side to invest in industrialization and the demand side to foster stock owners in adopting offsite solutions.

Overall, substantial investments in **massive offsite construction and renovation can have significant returns in regional economic uplift of local supply chains and communities**, while accelerating the run towards 2050 climate neutrality and intermediate 2030 targets.

3.3 State-of-art : from literature to EU funded projects and market initiatives

The application of industrialized deep renovation has been largely investigated in the **literature**, even if offsite new construction is still much more known and examined (as evidenced by the publications on its benefits in paragraph 3.2). Research is focused on envelope elements, HVAC components, technologies for harvesting renewable sources, and BIM as design and management tool for such approach. The performances of these technologies are usually evaluated through both laboratory tests and on-site monitoring at the scale of single buildings located in specific climatic contexts. Most studied solutions are timber framed integrated façade panels, while steel frames, precast concrete and multi-functional roof elements are less explored (Pernetti, Pinotti and Lollini, 2021).

Beside the ongoing literature investigations, current practice tends to deal with minor and single interventions (e.g., wall or roof insulation, window replacement, installation of new boilers or heat pumps, integration of a photovoltaic system, etc.) that are implemented without an overall coordination and organic vision of the whole building performance. The reason is linked to several barriers that involve technical, financial, and social aspects of IDR. In recent years, such obstacles have been mainly addressed by various **research projects financed by the European Union** (D'Oca *et al.*, 2018). Indeed, they do not only focus on the development of prefabricated technology sets, but they also tackle viable financial, business and operational models. In this sense, it's worth to underline that, even though the industrialized component is not always mentioned, the selected list deals with crucial challenges towards the market uptake and the replication of deep renovation (offsite, where possible). The most relevant funded projects (up to date) have been selected and reported in **Appendix B**. Only the ones specifically targeting the non-residential markets or having a broader focus on entire districts, cities or energy communities have been excluded. The projects addressing generically the public stock have been included since a portion can be referred to social housing. The source databases are:

- **CORDIS** for H2020 (2014-2020) and Horizon Europe programs (2021-2027) (EU Publications Office, 2023)
- **Keep.eu** for Interreg projects (both 2014-2020 and 2021-2027) (Interact, 2023)
- **LIFE public database** for LIFE projects (2014-2020) (CINEA, 2023)
- **CINEA** press release for LIFE Clean Energy Transition sub-program (2021-2027) (European Commission, 2022b)

In the appendix, four tables can be found:

- **Table B.1** shows all projects tackling with **industrialized and integrated technologies** (it excludes those projects focusing on ne singe component improvement such as heat pump, PV panels or, smart sensors or insulation materials, since no integration effort is involved);
- **Table B.2** lists the projects addressing **policy, government support, supply chain cooperation and stakeholders' involvement** (included topics are Energy performance certificates, renovation roadmaps, broad business model analysis, skilled training programs);
- **Table B.3** highlights **digital related projects** (BIM platforms, data gathering, dynamic certificates);
- **Table B.4** refers to projects focused on **financial, contractual and procurement aspects** (such as One- Stop- Shop, Energy Performance Contracts, innovative long-term finance schemes);

Around the European Union the **private initiatives of cutting-edge companies** developing prototyped industrialized solutions for new constructions but also for deep retrofits are increasing and can be found among the partners of the above-mentioned EU projects. The result is the cooperation among R&D departments of different realities (producers of façade panels, windows, ventilation machines, photovoltaic etc.) which launch on the market new integrated elements and start testing them on private and small-medium sized buildings. Even if, most of the currently developed offsite manufacturing uses relatively traditional production lines, there is growing investment in automated plants from the leading players (McKinsey & Company, 2019). This bottom-up trend shows increasing interest in the industrialization of the construction process from the supply side, but it doesn't provide the sector with a strategic scale up of the interventions towards a common and diffused approach.

Taking into account the intrinsic limitations of scattered market initiatives or single pilot projects, **Energiesprong is the most successful and diffused industrial prefabrication model for deep renovation projects to date** (BPIE, 2022). It's an innovative market development initiative born in the Netherlands in 2010 and already diffused in France, UK, Germany, New York State and Italy. It's a deep industrialized renovation program that uses a comprehensive supply chain approach to enable the achievement of net-zero energy and attractive retrofits by implementing offsite technologies such as prefabricated facades with windows and ventilation system integrations, insulated rooftops with solar thermal and photovoltaic panels and smart heating and cooling installations. The refurbishment comes with a rapid onsite installation and a long-year warranty on building performances (Fawcett, 2019). Furthermore, it is financed by future savings on both energy and maintenance costs over the guaranteed period without net additional investment expenditure to tenants, as shown in **Figure 8**. All the Countries that applied Energiesprong initially targeted a specific segment of the residential sector, that is social housing providers allowing faster demand aggregation, as explained and explored in Chapter 4.

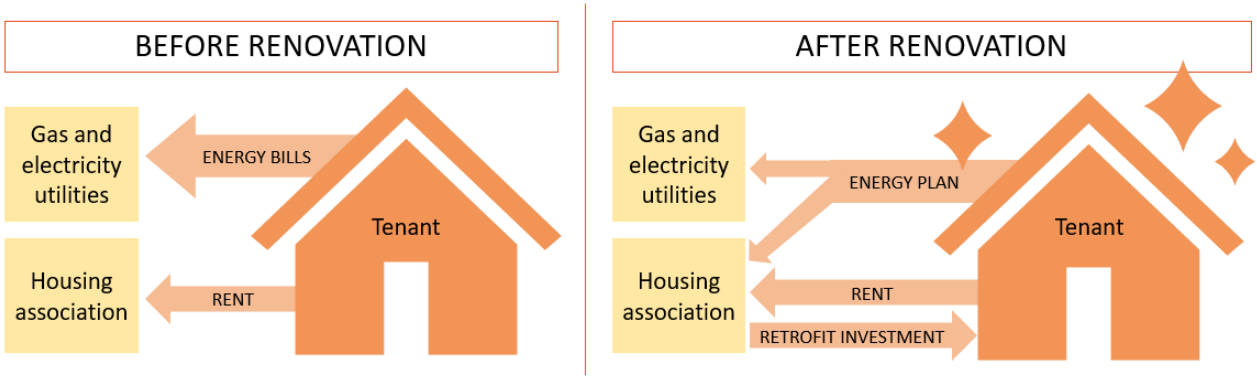


Figure 8 *Energiesprong model and the main cash flows before and after the renovation*

CHAPTER FOUR
Energiesprong renovation model and its European implementation

"Building for tomorrow, free of the compromise of today, because we all share the same home"-

This is Energiesprong claim that, in one simple sentence, highlights both the environmental and social sustainability of the model, together with the commitment for a fair transition and liveable future.

4.1 The analysis of Energiesprong innovative business model

With the ambition to be adopted at scale to improve the energy efficiency of the housing stock, Energiesprong is built on four main parameters for success (EFL, 2016):

- **Quality** – "*The retrofits need to be good. The makeover comes with a 30-year warranty guaranteed by the company delivering the solution. This includes both the warranty on energy, but also on the comfort and the indoor climate. This warranty also makes financing of a bank much easier and helps people trust the new technology. The makeover includes a maintenance contract*".
- **One-week delivery** – "*As there is never a good time to give your house a complete makeover, the refurbishment needs to be done within one week. This requires suppliers to think about prefabrication. Industrializing the process is necessary to get to the right the price-quality level*"
- **Affordability** – "*The savings on the energy bill should pay for the retrofit. As industrialization has not been picked up yet, the price is still high. The business case consists of a combination of energy costs savings and required maintenance work of the houses. These two budgets are combined in an investment that allows for the refurbishment*".
- **Attractiveness** – "*People are not interested in changing their house just to solve a technical issue. If you want innovations to be picked up by masses, you have to make them feel good about a solution. The suppliers play a crucial role in attracting a larger group, and key is to deliver a nice house where people want to live in*".

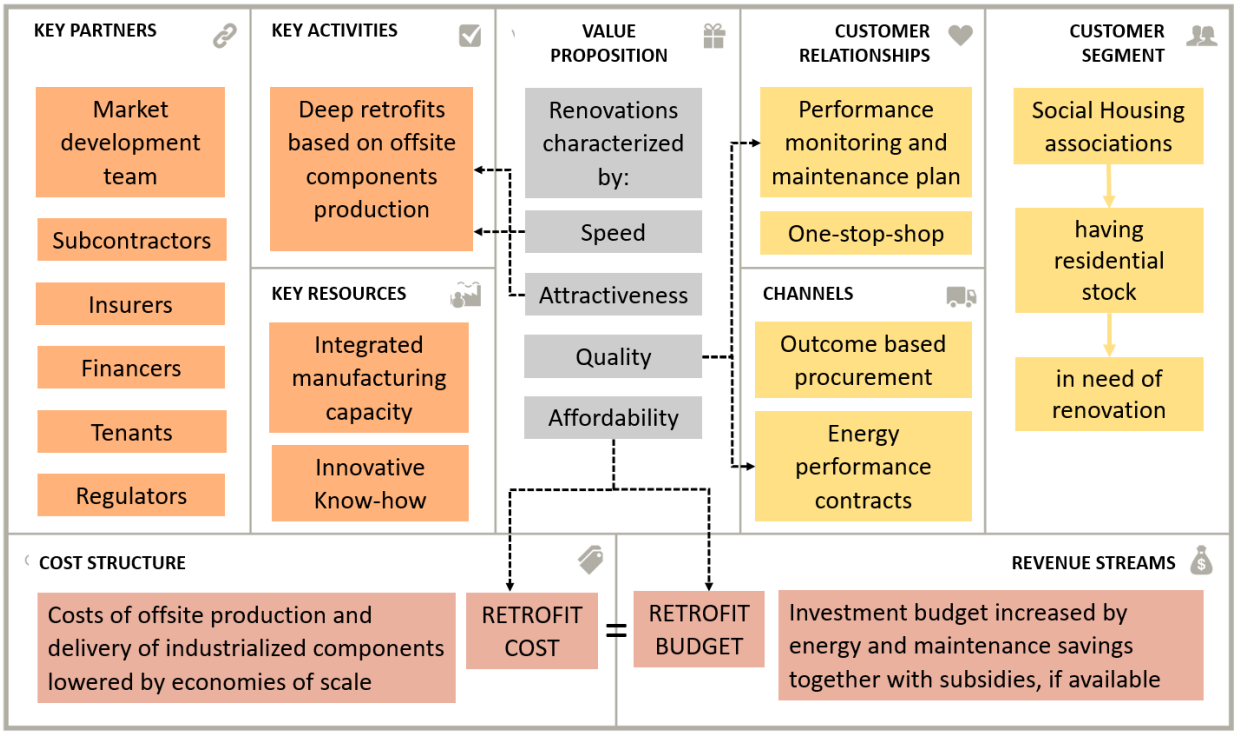


Figure 9 *Energiesprong business model canvas*

Within the framework of Energiesprong business model, quality, speed, affordability and attractiveness can be considered its **value proposition**. A business model is a strategic framework exploring how a specific entity creates, delivers and capture value. In order to better understand how such principles combine to deliver a successful approach to deep industrialized renovation, the business model canvas is applied and analysed, as represented in **Figure 9**.

The **customer segment** that better suits the proposition has been identified in Social Housing associations having private or public residential stock in need of energy-efficient interventions. The reason lies in the fact that, compared to private homeowners, they offer a unique opportunity to deliver effective retrofits programs at scale. Indeed, they can rely on: expert knowledge of their stock, asset management strategies in place, understanding of occupants behaviour, awareness on utility bills arrears among their tenants, track record of innovation and established trade relationships with suppliers, efficiency through massive purchase and partnerships with government and service providers (Sovacool *et al.*, 2020). All these aspects enable Energiesprong to work closely with social housing providers to identify suitable buildings, secure funding, and coordinate the retrofit projects. Dealing with few subjects managing a high number of buildings is crucial to cluster them in a number of typologies to which innovative industrialized interventions can be applied. In the different countries, a first tentative towards stock categorization has been made by brokering large **volume deals** across different housing organizations (a sort of commitment agreement) to create the momentum needed for stakeholders to act simultaneously and create a viable market to entice suppliers to invest in digital offsite manufacturing. New models of delivery that drive innovation, collaboration and scalability can, then, take shape and create a competitive supply chain that would benefit later also other market segments. On the contrary, the private sector is hard to enter at first due to the combination of financial risk and uncertainty on what the impact will be on the value of a house.

However, moving to the delivery **channels** of the proposition, things can get more complicated when dealing with public social organisations with respect to private providers, due to procurement obligations. Indeed, the fact that one of the most successful renovation initiatives, Energiesprong, started in the Netherlands is not accidental: it is also made possible because the Dutch private not-for-profit social housing providers were able to challenge the market as companies, not as public sector bodies, tied to EU public procurement rules (EU Horizon 2020 HEART project, 2020).

In the other countries, mainly France, United Kingdom and Italy where public associations are more diffused, their stock can be renovated only through call for tenders looking for suitable contractors on the market. According to European and national Procurement Code, there are different procedures (open, restricted, negotiated, competitive dialogue and innovation partnership) that can be chosen depending on the tender object specifications. For traditional interventions, open, restricted and negotiated procedures are usually selected because retrofits requirements are well known and can be already listed by the public housing organization in the call for proposal. If the social provider is looking for more innovative solutions, as it is the case of Energiesprong, competitive dialogue and innovation partnership are used, which is quite a disruptive novelty in the backward construction field. While they both are procurement procedures that involve interchange between the contracting authority and potential suppliers, there are some key differences between them:

- **Competitive dialogue** is used when the contracting authority faces complex projects or requirements that cannot be fully defined upfront. The purpose is to engage in discussions with potential suppliers to explore different approaches, clarify specifications, and find the best solution. The type of interchange is based on discussions, exchange of information, and exploration of different solutions. Competitive dialogue typically involves a shorter duration and leads to a subsequent procurement process where the contracting authority issues tenders or requests for proposals to the participating suppliers. The competition is based on the solutions proposed during the dialogue phase.

- **Innovation partnership** is employed specifically for situations where the contracting authority seeks to develop innovative solutions that are not available in the market. It aims to establish a long-term partnership between the contracting authority and one or more suppliers to jointly develop and subsequently procure innovative products, services, or works. The interchange consists in joint research and development activities, testing of prototypes, and close cooperation to develop innovative solutions. Innovation partnership is a long-term arrangement where the contracting authority enters into a partnership with one or more suppliers. The procurement is based on the outcome of the partnership and may involve negotiated procedures or subsequent competitive processes.

To summarize, the main difference between the two procedures is that competitive dialogue assumes the required solutions are already available in the market, but their optimal implementation needs to be determined through dialogue. The innovation partnership, instead, specifically addresses situations where the contracting authority seeks to develop innovative solutions that are not currently available in the market. Contextualized to the Energiesprong model, the former is used when renovation suppliers have already developed specific industrialized products which are not traditionally used by public housing associations. The dialogue is needed, in the first projects, to redact call of proposals which specify performance to be reached rather than technical solutions, leading to an outcome-based procurement. In this way the offsite integrated solutions can compete with more traditional ones and win the bids in which they are more cost-effective. The innovation partnership is, instead, used when public housing associations are so engaged with Energiesprong that a joint effort in put in place to develop new innovative retrofits components which better fit their needs, according to their specific housing stock.

Furthermore, once the supplier has been selected, different types of contracts can be awarded (procurement of works or services, public private partnerships - PPP including EPC and project financing, concessions, framework agreements).

The **Framework agreement** is a flexible procurement arrangement that establishes the terms and conditions under which specific contracts can be awarded during a predetermined period (usually several years). This typically involves a competitive procedure (which could also be a competitive dialogue or an innovation partnership) where suppliers submit their proposals, and the contracting authority evaluates them based on specified criteria. The selected suppliers are then awarded a place on the framework agreement. When the contracting authority needs to make an intervention covered by the framework agreement, it issues a call-off contract. The listed suppliers participate in mini-competitions to fulfil the call-off contract based on the agreed terms and conditions. This process eliminates the need for repetitive and time-consuming tendering processes while ensuring fair awarding. Throughout the duration of the agreement, the contracting authority may evaluate the performance of the suppliers to influence the upcoming call-off contracts.
In the Energiesprong model, the framework agreement as been tested in the UK only with the goal of predefining all the offsite solutions providers that could deliver, over the years, a predefined number of renovations when needed (Energiesprong UK, 2020). Every subsequent call-off contract has been made to increase the volume to be renovated, as long as in the previous round the requirements asked by the public housing organizations were all met. Such procedure was very effective both for the supply side (that obtained a guaranteed building volume which motivates industrialization investments) and the demand side (which sees a gradual increase in the number of units involved, upon successful completion of the former retrofits).

Another Energiesprong peculiarity, even if it's not a novelty, is the adoption of **Energy performance contracts (EPC)**. In public procurement it is a specific subcategory of PPP targeting energy efficiency services and works. It was first developed in the 1970s and gradually become one of the most used approaches to energy savings and emission reduction. In general, these deals are arranged by a private entity (such as an energy service company – ESCO) that provides performance-based projects to the public organization taking both risks and earnings till the contract is in place. In recent years, the promotion of the energy efficiency of public buildings

and environmental and social sustainability became a central issue so more and more EPC contracts have been signed but their application to industrialized deep renovation is very rare. Indeed, they are usually applied for light interventions involving photovoltaics panels that have a shorter return on the investments and can easily exploit energy cost savings/revenues to repay the project costs.
The peculiarity in the Energiesprong model is the use of offsite components that, thanks to high quality and long durability given by the industrialized production, enable the setup of long-term performance guarantees (usually up to 30 years). Such guarantees can extend the payback time considered by ESCOs and, thus, introduce more expensive elements (insulating wall and roof panels, new windows) within the renovation model, taking buildings to net zero energy levels. To deepen all the benefits deriving from the adoption of long-term energy performance contracts read paragraph 3.2. It's worth mentioning that the EPCs is a delivery channel that is used also by private social housing companies since it can be a contract between all kind of parties. The only different is that they can chose whatever suppliers without the need of public tendering.

However, moving to the **customer relationships**, the provision of Energiesprong renovations implies connections not only with the social landlords but also with their tenants which are the actual recipients of the interventions. Whilst the interface is initially with the housing provider, significant emphasis is placed on household engagement which is crucial for the successful outcome of energy performance contracts. Generally, conformity has to be demonstrated in the design phase through studies and simulations and is only very rarely verified from actual consumption data captured after delivery, when the building is already in use. Due to EPC and long-term guarantees, the performance monitoring and maintenance plan over time is key to check that the NZE target is met. They are both aspects that can be easily solved by installing proper Building Management Systems and organizing preventive checks and scheduled components' replacement. What is harder to be controlled is the behaviour of tenants. For instance, monitoring requires the prior consent of the residents for data to be used in compliance with the General Data Protection Regulation. For this reason, the **tenant engagement** has been crucial in many Energiesprong renovations, starting from pre intervention to construction phase to delivery till the operational phase of the building.

If before the renovation, to achieve consensus from tenants to start the works, the emphasis goes on the aesthetic and comfort improvement of the house, importance placed on the notion of energy neutrality must increase once the intervention is complete. The situation can be often tricky, so landlords organize discussion meetings with residents to demonstrate the day-to-day benefits of Energiesprong and to address their questions and concerns. They, even, incentivize them to go full-electric by covering the costs associated with ditching gas, a change that can put people off the project, due to the need to acquire a whole new set of appropriate pans (Pellegrino, Wernert and Chartier, 2022).

However, most problems come after delivery: occupants should have the capacity to use the digital devices to track their consumption and manage the equipment independently, but changes are so profound that they do not immediately collaborate, and a gap remains: the issue of behavioural habits that are unsuited to a high energy performance building. This situation may be problematic both for tenants and landlords. The former will find themselves having to pay for excess consumption (which may equally be the result of free choice or of a misunderstanding of how the technical systems work), the latter have to face many complaints despite the effort dedicated to improving building performances and occupants' comfort. Most successful projects teach that tenants need to be guided during the whole process to get used to their new habits and perceive the enhanced living and economic conditions. In fact, the issue of consumption reductions, although seen in terms of saving money rather than saving energy, becomes central and attracts unconditional commitment to the project even from households that had expressed doubts or dissatisfaction in the previous stages.

Moving to maintenance, in the specific case of Energiesprong it can be managed by the one stop shops (OSS).

One-stop-shop models refer to situations where teams, consisting of experts from various sectors, collaborate to handle every aspect of a renovation project. Actors include architects and designers, constructors, energy-efficiency experts, market and financial experts, technology suppliers, strategy and operations planners. The goal is to replace the fragmented renovation process with an integrated and holistic approach. In traditional renovations, indeed, homeowner need to make all major decisions (taking contact with the suppliers, investing time and money, taking risk) and it is supported only through available incentives and information. This usually makes several barriers arise preventing renovation to happen. Rather, OSSs represent and manage the major steps of the renovation journey interacting with the customer and supporting him from pre-renovation audits and post-renovation quality control (Brown, 2018).

In the Energiesprong model, OSS is not only an added value for the customer, but it also comes from a necessity. Indeed, the industrialization of components intrinsically require the coordination of several solution providers for an effective integration. Usually, it is the panel manufacturer itself that has enough managerial capacity to set all partnerships and agreements with subcontractors, energy utilities and facilities for the maintenance, but it can also have only in-house some activities, still being the main point of contact with the housing organization. If the panel manufacturer is a small enterprise the role of OSS is taken by an external general contractor which has strong relationships with the upstream supply chain (EU Horizon 2020 project STUNNING, 2019).

Moving to the financial model, made of **cost structure** and **revenue streams**, one of the strongest goal of Energiesprong model is to equal the retrofit cost, borne by the social landlord and charged by the OSS, to the retrofit budget (energy and maintenance savings, renewable revenues and subsidies) to reach cost-neutral business model for social landlords (Bianco *et al.*, 2022). Indeed, if the first pilot projects are supported by national and European Union innovation funds and a range of local partners in these respective countries, the idea is that when the industry is at scale, the cost of installation will be offset by long-term savings and income equal to or greater than the value of the work. It is worth underlining that the model is based on a strong and ambitious assumption: achieving economies of scale and learning rates, so that the financial model is viable based on energy costs savings and maintenance budgets alone - rather than reliant on external grants. Of course, sustainable third-party sources of finance will still be necessary to guarantee the upfront liquidity, especially for the private housing sector. Source of finance are, however, very country specific so they will be tackled in broad terms in paragraph 4.2.

Going back to the general framework, social housing organizations base their business case on transforming tenants' energy bills into an energy plan (Pellegrino, Wernert and Chartier, 2022).
In the Netherlands, the original economic model is based on tenants paying a sum equivalent to what they spent before for rent and energy, although energy is supposed to be zero after renovation. The whole amount is paid to the landlord (while the energy supplier only receives the subscription fee), who therefore receives, in addition to the rent, a sum of money, called the “energy plan”, previously paid to the energy supplier which is used to return on the renovation investment over the years. The baseline of the plan is set on tenants’ energy consumption of the last three years. This means that, if energy neutrality is not achieved, the household will ultimately have to pay more than before the renovation. As stated in the customer relationship section, the danger of this model is that it could expose tenants to a greater risk of energy poverty. For their part, landlords are also subject to heavy pressure in relation to occupants and to the EPV mechanism. Indeed, housing organizations lose their right to receive the money in the energy plan, which is paid directly to them by tenants, unless they are able to show that the building had generated the agreed quantity of energy and that any shortfalls are attributable to the behaviour of the occupants.
In France but also in UK, Germany and Italy, the economic model is slightly different since landlords cannot manage the energy for their buildings and rent levels are heavily controlled. In these cases, tenants continue to pay their bills, usually significantly reduced, to the energy supplier. Landlords benefit comes from selling the energy produced by the photovoltaic panels and reinjected into the grid. In addition, they can make

modest rent increases in line with the legal limits and can increase the service charge to the tenants. They have such right because they have carried out major energy efficiency improvements and maintenance. However, by contrast with the Netherlands, this model assumes that households spend less after renovation than before and that the reduction in the energy bill is much greater than the increase in the service charge and rent, so if there is any excess in consumption attributable to tenants' behaviour, total payment should still be lower than it was before the renovation.
However, there is no denying that the strong pressure social landlords have to decrease the consumption volume of the existing building stock social landlords, is reflected to the need for residents to adjust their behaviour to the requirements of the new technical and complex systems. building owners should not underestimate the importance of this adjustment for the overall economic model to function properly and bring benefit to all parts (Pellegrino, Wernert and Chartier, 2022).

Key activities are strictly linked to the realization of deep retrofits based on offsite components production. They need **key resources** to be implemented, such as integrated manufacturing capacity and innovative know-how. According to Energiesprong and to its first interventions, great improvement potential exists in converting the building sector to the development of integrated solutions that are industrialized instead of project-based and craftsmanship-oriented. This aspect is essential to decrease costs while achieving constant high standards of quality and a short completion time. Key activities and resources are not tackled further since they have already been analysed in paragraph 3.1 and 3.1.

Last but not least, to provide fast, attractive, valuable and affordable, different **key partners** are involved, even if the turn-key service is provided to the client through the one-stop-shop model. There are subcontractors, insurers, financers, tenants and regulators who are crucial, but they are always part of renovation ecosystems. What is definitively innovative in Energiesprong, is the introduction of a temporary intermediary called market development team (MDT) with the role of coordinate and integrate all business models features. Indeed, systemic innovations (in contrast with incremental ones) require complementary changes in supporting technologies, technical skills, cultural norms, user competences, organizational practices and policies (Brown, Kivimaa and Sorrell, 2018). Such changes can't be easily adopted by incumbent actors due to lack of necessary knowledge, capabilities or assets able to promote whole system transformation. In this context, innovation intermediaries are needed, being actors and platforms that positively influence sustainability transition processes by linking activities, skills and resources.
In Energiesprong, the market development team, being the intermediary, has three core roles (Brown, Kivimaa and Sorrell, 2019) :

- **Facilitating** which involves bringing together the key stakeholders. Project partners including large construction companies, social housing providers, local authorities and municipalities have been gathered (through events, publications and pilot projects) to create a shared vision for net-zero energy buildings and develop a diverse skillset and knowledge base.
- **Configuring** that is related to the design and modification of internal business model components. This involved intensive innovation program in partnership with contractors to determine what was technically possible, and extensive legal and policy work to develop proper procurement and energy performance contracts.
- **Brokering** which concerns external advocacy and market formation activities. The market development team played a critical lobbying role in raising financial and human resources, together with demand volumes and regulations changes (such as the placement of energy service charges on rents, performance-based subsidies etc.).

In **Figure 10**, facilitating, configuring and brokering roles are represented together with the business model areas: value proposition, supply chain (key activities, resources and partners), customer interface (segment, relationships and channels) and financial model (cost structure and revenue streams). Such intermediation

roles require to be reconfigured every time the Country of implementation changes, due to the different regulatory environment, industry culture and consumer expectations. Furthermore, the market development team should have a temporary role, since it is not the subject that undertake the retrofit and over time Energiesprong business model should become mainstream, with a broad self-sustaining market. The focus is intently on creating the conditions for sustainable uptake of retrofit innovations that will eventually no longer require intermediation. So far, it has been proved that the MDT neutral position has been crucial to overcome existing barriers and foster an open approach to innovation, where learning is widely disseminated rather than held within individual firms.

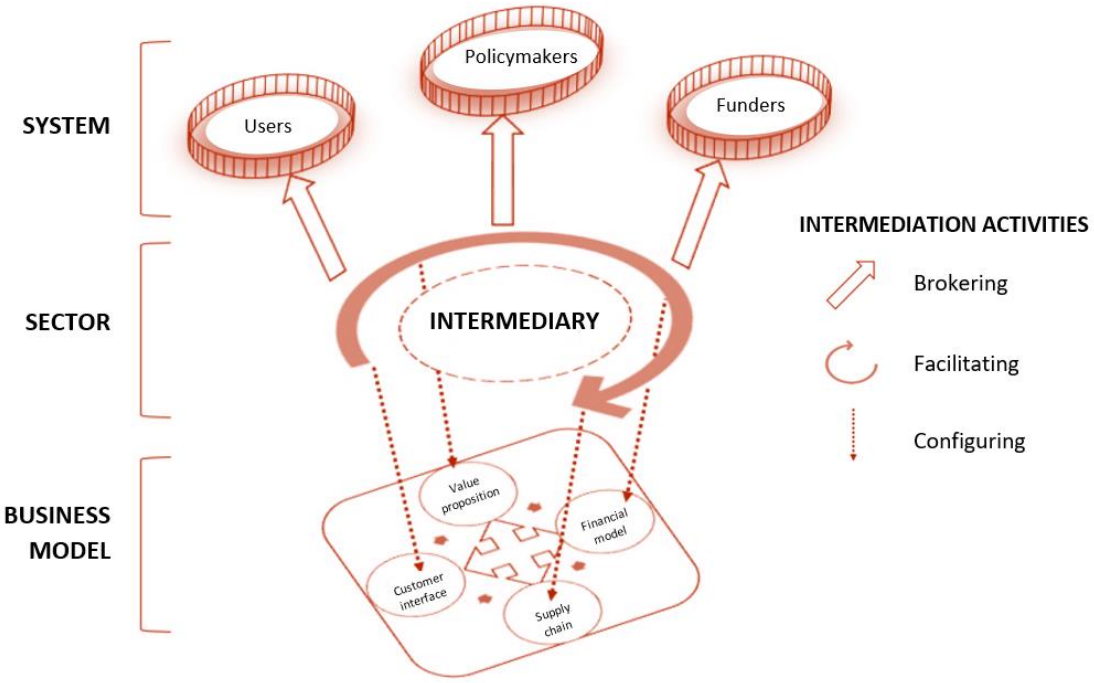


Figure 10 *Facilitating, configuring and brokering roles of the intermediary with respect to innovative business models. Source:* (Brown, Kivimaa and Sorrell, 2019)

To conclude, besides a successful business model which works also for a single intervention within the customer segment, the impact of Energiesprong renovations is negligible if there is no proper building stock ready to be retrofitted. In this sense the negotiation of delivery volumes and the targeting of the social housing market has been an effective strategy to catalyse diffusion processes. Indeed, working on industrialization and supply innovation is not sufficient to produce a positive and significant impact, as shown in **Figure 11**: the annual number of retrofits is given by the minimum of annual demand (that collectively asks for a different type of offering) and annual production capacity. For this reason, one of the main roles of the market development team has been, in all countries, facilitating the matching of supply and demand on the large scale.

Overall, although the intermediation and constant work of MDTs helped facing a wide range of challenges, some barriers persist depending to the different contexts and project typology. They are mainly technical, financial, legal and social. It is frequent that existing structures limit the choice of the technical solutions that can be used, together with the fact that some building have very little information of their condition before the renovation. Furthermore, interventions may be expensive and request a high investment, which is hard to access due to the inadequacy of financial models and lack of effective incentives. Policy improvements and changes to encourage energy efficiency take time and high advocacy efforts. The payback period for renovation may take even 30 years, and it's difficult to equally split costs and earnings between owners and

tenants who may lack of knowledge, engagement and proactivity. Context specific obstacles, achievements and lesson learnt are briefly described in the following paragraph.

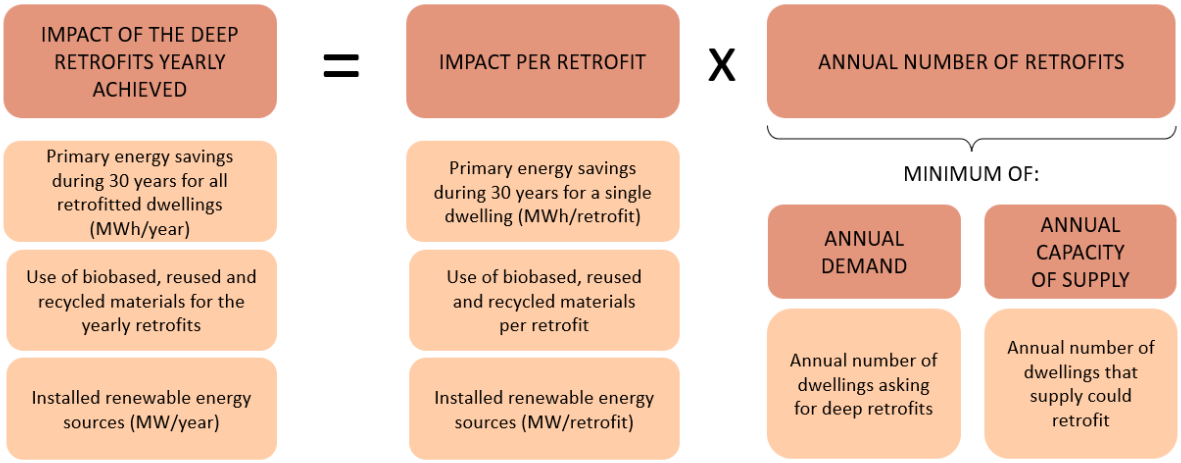


Figure 11 *Calculation of the yearly impact of deep renovations: how is it affected by both supply and demand*

4.2 Energiesprong countries overview and their distinctive features

Before delving into Energiesprong modalities and achievements in each European country, it's worth understanding how the stock they have targeted is structured and organized. In this respect, an analysis on the different social housing models opens each dedicated subparagraph. Information is taken from Housing Europe[18], firstly named CECODHAS. Its research branch, the Observatory, aims at providing strategic and evidence-based analysis in the field to support policy work for the delivery of social houses. Eight of its reports have been summarized and merged to deliver an updated and exhaustive overview, highlighting the aspects mostly connected to renovation and its financing. When further insights are provided, the related sources are properly cited. The analysed papers are:

1. Review of social, co-operative, and public housing in the 27 EU Member States (Czischke and Pittini, 2007)
2. Financing social housing after the economic crisis (CECODHAS Housing Europe, 2009)
3. The nuts and bolts of European social housing systems (Pittini and Laino, 2012)
4. Study of financing of social housing in 6 European countries (CECODHAS Housing Europe, 2013)
5. The financing of renovation in the social housing sector (Housing Europe, 2018)
6. The state of housing in the EU (Pittini, 2019)
7. The state of housing in Europe (Housing Europe, 2021)
8. The state of housing in Europe (Housing Europe, 2023)

According to the social housing classification presented in 2.3, **Table 4** provides a snapshot of the different social housing models among Energiesprong countries. It's worth mentioning that the analysed countries are those with the broader experience of social housing providers in the renovation activities due to the importance and size of their stock. In most of them the related social stock tends to show better energy performance than privately owned homes. They are not, then, representative of the whole European

[18] Housing Europe is the European Federation of Public, Cooperative and Social Housing. Since 1988 it's a network of 46 federations gathering 43.000 housing providers in 25 countries. Together they manage around 25 million homes, about 11% of existing dwellings in Europe. See: https://www.housingeurope.eu/

situation, but they are the most advanced ones which have already dealt with energy efficiency in the past and are now looking for innovative and effective retrofit processes. Indeed, E-F-G labels still account for 10% to 20% of social dwellings so efforts are nevertheless required to reach current stringent climate goals, even for the best performing providers.

Table 4 *Social housing models among Energiesprong countries*

COUNTRY	SECTOR SIZE	TYPE OF GOVERNANCE	ALLOCATION CRITERIA	FORMS OF SOCIAL TENURES	FINANCING CHANNELS
Netherlands (see 4.2.1)	> 20%	private not-for-profit housing org.	Universalistic	Rental Sale to sitting tenants Shared ownership	Revolving fund model
France (see 4.2.2)	10% - 20%	Public, private, and cooperative companies	Targeted residual and generalist	Rental homeownership Cooperative Shared ownership	Savings scheme model
United Kingdom (see 4.2.3)	10% - 20%	Municipal and private companies	Targeted residual	Rental Right to buy Shared ownership	Debt equity model
Germany (see 4.2.4)	0% - 10%	Private, municipal and cooperative companies	Targeted residual and generalist	Rental homeownership Cooperative	Tax privileged model
Italy (see 4.2.5)	0% - 10%	Public, cooperative, and private companies	Targeted generalist	Rental homeownership Cooperative	Integrated real estate funds

4.2.1 Netherlands

The Netherlands has the **largest portion of social housing in Europe**, with about 450 registered housing organizations providing around 2.3 million dwellings, which represents the **29% of the total housing stock** and the 69% of the rental one. Even though there is not a single definition of social housing in the country, the provision of social housing is regulated by the Dutch Housing Act (2015) following a 2010 European Commission decision that has defined it as the delivery of below-market-price dwellings and other related services to a target of less advantaged groups and key workers identified by the public authorities.

Who provides social housing?

Woningcorporaties are recognized private for-non-profit social housing organisations (262 associations and foundations) with the legal bond to operate in the housing field and to give priority to lower-income and disadvantaged households. They are the most important players on the Dutch housing market, and they work under the supervision of the national government, on the basis of a registration which identify them as “social enterprises”. Woningcorporaties are gathered in the Dutch federation of social housing companies called Aedes which supports them in local development plans. It has also a seat at trade unions tables to agree on collective employment agreement. Although the legal framework is set up by the State, the social housing organisations act independently with their own objectives and financial responsibilities. Besides building, maintaining, selling, and renting social housing stock, they provide other services (employment, education and care) to the tenants, having different criteria for funding/taxation and representing a low percentage of their activities. Undertaking these commercial activities has a double purpose: on one hand, by offering various packages of services to a broad selection of population groups, they are better prepared to guarantee the availability of affordable housing for those with the lowest economic opportunities; on the other hand,

by diversifying their activities, they reach a broader welfare provision which can raise the quality of life in the neighbourhoods.

Who can access social housing?

Before the 2010 European Commission decision and the **2015 Housing Act (Nieuwe Woningwet),** access to social housing had no income restrictions, with allocations criteria varying according to the local/regional situation. Currently the universal approach has been limited, targeting a specific group of people, primarily defined in terms of income ceilings and vulnerability (this means that 90 % of the managed housing units must now be rented to low-income households). Special attention is also given to accessibility for elderly people, immigrants and neighbourhoods' social mix. However, due to both housing shortage and increase in rental prices especially in urban areas, many middle-income households, who can no longer access social housing risk to be pushed out of cities. For this reason, a recent draft legislation has proposed the easing of some allocation criteria to offer also mid-priced rental housing, taking into account the household composition and the prioritization of key workers (such as teachers, nurses and police) to prevent labor shortages.

How is social housing financed?

Since 1993, with the so-called Brutering (balancing-out) agreement, the social housing sector became financially independent from the central government since all credits (subsidies) and debits (loans) were settled at once. Housing associations currently finance their investments by capital market loans with interest rates about 1% lower than all other bodies, thanks to a three-level financial safety structure made by:

- **the Central Fund of Social Housing (CFV)** which is an independent public body acting as a supervisor (through a biannual report on solvency and liquidity of Woningcorporaties) and providing support to the organizations that are incurring in financial difficulties.
- **the Guarantee Fund for Social Housing (WSW)** which is a private organization created by Woningcorporaties themselves to be a **Revolving Fund**, a fund established to give loans to members to be invested for specific purposes. The repayments are made by the same members and can be used again for the same purposes only. In this way, more precarious social housing organizations can benefit from favourable conditions to finance their activities, helped by more economically efficient ones, guaranteeing the sustainability of the sector. The fund's security reserve (working as a proof of financial stability for the bank) is established through the fees organizations have to pay when contracting a loan with the WSW guarantee (which has a triple A rating).
- **State and local authorities' intervention** (50%/50%), which is the last resort, in case the other two instruments are not enough to fix economic problems. It provides interest-free loans having a backup role.

The 3-level security system is solid, represents a case of risk pooling and, therefore, it guarantees the solidarity and financial health of the sector. Due to the large cumulated assets the associations are able to spread the risks of bankruptcy and can get access to more beneficial interest rates. Beside this structure, housing associations can also handle internal financing or take loans from the capital market but usually with the WSW involvement interest rates are 0,5% lower. Housing corporations take loans from banks on the basis of the yearly planned activities, and they manage their loan portfolio (75% of the costs) as well as resources from their own equity (25%) to complete the planned projects/activities.
From a fiscal point of view, instead, there is no special tax advantage on VAT, while from the demand-side housing benefits are available for tenants to help them pay their rent, according to income and age. Yearly maximum rent adjustments are possible and they're mainly linked to inflation levels.

How is social housing traditional renovation organized?

In the Netherlands the average social dwelling size is 80 m^2. Peak construction was recorded between 1960 and 1990, so the average age is about 41 years. 53% of social dwellings are collective buildings (flats), 41% are individual dwellings (houses) and 6% other houses (for groups). As for energy mix, 93% of the stock has a central gas heating system while the 7% has district heating. Housing corporations are already at the forefront of sustainability and renovation efforts, with **over 50% of their dwellings having an energy label A and B, with only the 11.8% at E, F, G level.**

Besides particular agreements, social housing associations have a maintenance schedule over the building lifetime, which leads to planned renovation, integrating energy efficiency measures outsourced to contractors. In 2015, in line with the kick-off of Energiesprong, traditional zero energy home renovation (including renewable energy sources) costs between € 65.000 and € 85.000 per dwelling, depending on the nature of the works.
Most investments in energy efficiency comes from the housing associations rental income (75%) while the 25% comes from government subsidies, called STEP, which are proportional to the energy index reached after the works. Furthermore, through a housing cost warranty, the rent after renovation measures can be increased in proportion to (but no more than) the theoretical decrease of the energy bill.

What are the main policy developments and trends towards renovation?
Since 2007, government is focusing on extensive regeneration of city areas. Social Housing organizations have also committed themselves to significant investments in that direction and in reducing emissions of the build environment. Indeed, in 2012, through the Dutch Covenant on Energy Saving in the Rental Sector, a number of housing corporations have set up a voluntary agreement, committing to reach an average B energy performance level in their building stock by 2020.
Along those lines, the 2015 new housing act also established the first official 3-years performance agreements structured around meeting clear social objectives, output targets and consultations with tenants' groups to deliver better tailored services. They are negotiated by housing associations, tenant organizations and municipalities to find optimum conditions in a contest of tax burden on corporations, which ultimately translates in rents rising faster than inflation, less renovation and slow pace of new construction.
In 2018, a new social rent agreement between Aedes, the Dutch federation of social housing companies, and Woonbond, the Dutch tenant association, has been signed addressing once again the issues of affordability, availability and sustainability through a limited national framework supplemented with local arrangements. Besides setting rent capping limits and allowing specific customization for tenants economically in need, the principle at the base of the Agreement states that the quality of the dwelling should form the basis of the rental price policy (Aedes and Woonbond, 2018).

In this perspective, since sustainability has a double advantage (reducing CO2 emissions but also lowering tenants' discomfort and housing costs) it should be a shared responsibility of landlords, tenants and the government who should all contribute financially, according to their ability. For this reason, the 2018 Agreement sets a remuneration table for sustainability investments which allows housing associations to **raise the rent proportionally to the energy label reached after the renovation**. The mechanism works as follows: the government has a Property Valuation for social housing which sets the maximum rent margin given by a certain quality measured in points. The average point price is around 5€/year. The energy rating gives more quality and therefore the social housing association can ask the tenant more rent. For instance, for an apartment renovated from label D to label A++, the landlord will be allowed to raise rent by 29 points (40-11) multiplied by 5€, which means an extra of 145€ per year.
The idea is that the average savings on energy bills, that tenants experience, are expected to amply exceed the maximum compensation fee, agreed between Aedes and Woonbond, so social housing association can guarantee a decrease of total costs after energy measures are taken, based on a housing cost warranty.
However, when the renovation occurs in occupied dwellings, the current tenant needs to agree with a higher rent before the housing association can invest in energy efficiency measures. Therefore, 25% do not ask for extra rent to current tenants so they need no permission for the investment in measures such insulation, new heating system or photovoltaic panels.

With the sign of the recent **National Performance Agreements in June 2022**, a paradigm shift took place: the **abolition of the landlord levy** (a tax introduced in 2013 for renting out homes at a rate below 737 euro) since January 2023 has free up €1.7 billion to be invested, annually, in affordability, sustainability and availability by housing corporations (Aedes, 2022).

Making the built environment more sustainable is one of the main tasks at the basis of the Agreement and it is essential that all parties in the housing market participate to the energy transition. Four are the main commitments that emerges:

- **450.000 natural gas-free social houses by 2030**, as part of the district-oriented approach, in which municipalities are the first to provide support for natural gas-free districts among all residents. Indeed, in order to be able to achieve the goal, social housing corporations need to have a defined transition vision for heating elaborated by local governments (with the support of The National Local Heat Transition Program) by 2024 at the latest, to understand what heating system are considered acceptable and desirable (hybrid heat pumps, connection to district heating and so on), what incentives are available and consequently assess the feasibility of the agreement.

- **Insulation of 675.000 existing social houses in a future-proof manner by 2030**, which means they can be heated at a flow temperature of 50 degrees maximum without having to be tackled again. It is up to corporations to determine which buildings will be insulated, including the 450,000 houses selected to become natural gas-free. In 2025 the feasibility of the task will be evaluated to decide if some adjustments might be needed. The commitment to insulate 675,000 homes goes hand in hand with the existing agreement to accelerate the **phase-out of all social rental houses with an E, F and G label** by 2028 at the latest, apart from municipal, provincial, and national monuments and buildings designated for demolition (the estimated volume is around 250.000 dwellings). To avoid the overload of the construction industry and trigger economies of scale, housing corporations are encouraged to actively commit themselves to bundling demand and to seek cooperation with the support of the proper subsidy schemes.
  Since the tenant engagement is also extremely important, so far 70% of occupants must approve the sustainability proposal made by the associations before works can be started. This ensures that corporations come up with a good plan and that tenants are involved in the improvements that are made to their dwellings. However, it must be prevented that the right of consent can unintentionally have a delaying effect, through an effective bill elaboration on the manner.

- **Free of charge insulation measures for tenants,** waiving the application of the compensation table included in the previous Social Rental Agreement. This change of course leads to a reduction in housing costs for occupants and makes sustainability more attractive for tenants, thus leading to the desired acceleration. Furthermore, low-income tenants in homes with an E, F or G label will benefit from targeted rent reductions since 2024, waiting for free insulation before 2028.

- **Renovation of all dwellings in a poor state of repair by 2026**, unless there are concrete demolition plans. Indeed, beside energy transition, housing associations are also struggling with problems related to moisture, mold, lead pipes, aging stock, resulting in a need for (large-scale) restructuring and improvements, task to be tackled together with the sustainability one.

Based on the National Performance Agreements, the total target investment target borne by Housing corporations, in the period from 2022 to 2030, is approximately € 119 billion. The majority goes to new construction, followed by 46 billion for sustainability and quality improvements. The annual investment cash flow is, then, estimated to be increased by approximately € 1.45 billion for sustainability and €200 million for quality improvement with an additional loss of earnings of around 60 million due to the abolition of rent increase. These investments are made possible by the abolition of the landlord levy (Aedes, 2022).
However, considering such ambitious targets, resources taken to renovate homes is a factor that needs attention from policymakers to maximize the benefits coming from the levy abolition. Indeed, the national electricity grid is currently at capacity due to the increase in the use of solar panels and other electrification efforts. Furthermore, available skilled labour is lacking. Supply chain and grid access are creating real bottlenecks challenging the whole sector.

What are the main Energiesprong highlights?

Implementation date	2010 – 2016 2017 – on going
Market development team	Platform31, non-profit network of organizations Stroomversnelling, non-profit association
Funding structure	50 million (government 2010-2016) 6 billion (WSW Social Bank loan) 3.6 million shared (transition Zero, H2020 2016-2019) 5.4 million shared (E=0, Interreg, 2016-2019) 11.6 million shared (Mustbe0, Interreg, 2019-2022)
Achieved results	5700 retrofitted houses
Expected results	14400 planned retrofits

According to the overview made by the European Construction Sector Observatory (European Commission, 2017), Energiesprong was commissioned by the Dutch Ministry of the Interior and Kingdom Relations through **€ 50 million government funding** (distributed from 2010 till 2016) to meet the objectives of the Innovation Agenda for the Built Environment, a compilation of innovative policies focused on construction and energy transition. Energiesprong's first goal was to create the conditions for affordable net-zero energy retrofits to take hold in the mass market by 2020. It targeted to deliver solutions to 2.500 new buildings (which are not in the scope of this thesis), making them energy-neutral, and 2.500 renovated ones, allowing them to reach from 45% to 80% energy savings. It was firstly implemented by **Platform31,** a non-profit knowledge-sharing network of organizations offering innovative solutions related to urban and regional development able to connect researchers and policymakers.

The first retrofits were piloted on terraced houses, and they achieved:

- 150 kwh/m^2 (70%) of total reduction in energy consumption from 20.000 kWh to 6.000 kWh;
- 1/3 savings generated by the energy produced on-site and 2/3 savings coming from energy efficiency measures;
- a cost of 130.000 € per unit.

By the end of 2013, thanks to economy of scale, 3D technologies and prefabricated materials, the cost per terraced house lowered to about 65.000 €, getting closer to the 40.000 € target. Overall, the accomplished energy savings have been:

- 45% in 800 existing houses
- 60% in 160 existing houses
- 80% in 258 existing houses

totalizing:

- 15.6% reduction in CO2/m^2;
- 19.4% reduction in the consumption of gas/m^2;
- 4.3% reduction in the consumption of electricity/m^2.

In 2013, Energiesprong also brokered the "**Stroomversnelling**" (rapids) **deal between six housing associations, four construction companies and other supporting organizations to retrofit to Net Zero Energy (NZE) 111.000 social housing dwellings (11.000 confirmed agreements with the prospect of a further 100.000)** divided into: terraced houses; four-story buildings and multi-apartments blocks, according to the scale up strategy shown in **Figure 12**. The three categories have a growing degree of complexity given by the rising number of floors which increase the height of the retrofit interventions and decreases the roof surface

available per dwelling for the installation of renewable energy sources to supply enough electricity for heating, hot water and appliances. Therefore, while terraced houses renovation have potentially reached the mass market, the innovation of technical solutions should be mature enough to be tested on the first prototypes for multi-apartments blocks. Stroomversnelling required an investment of € 6 billion, funded by the WSW Social Bank through a 40-year government-backed loan to the involved housing associations.

In 2014, while the market development team grew from 3 to 45 people, the number of housing associations part of the deal increased from 6 to 27, resulting in 200 pilot retrofits delivered.

In 2015, together with the roll-out of 2000 more renovation interventions, Stroomversnelling evolved into a **standing market initiative** becoming a network of more than 65 members among contractors, component suppliers, housing providers, local governments, financiers, energy system managers and other parties with the aim of increasing the pace of growth of NZE retrofits. In the meanwhile, other Countries joined the Energiesprong movement, establishing their own market development teams while the Netherlands expanded the NZE retrofit approach to commercial offices, schools, and care homes.

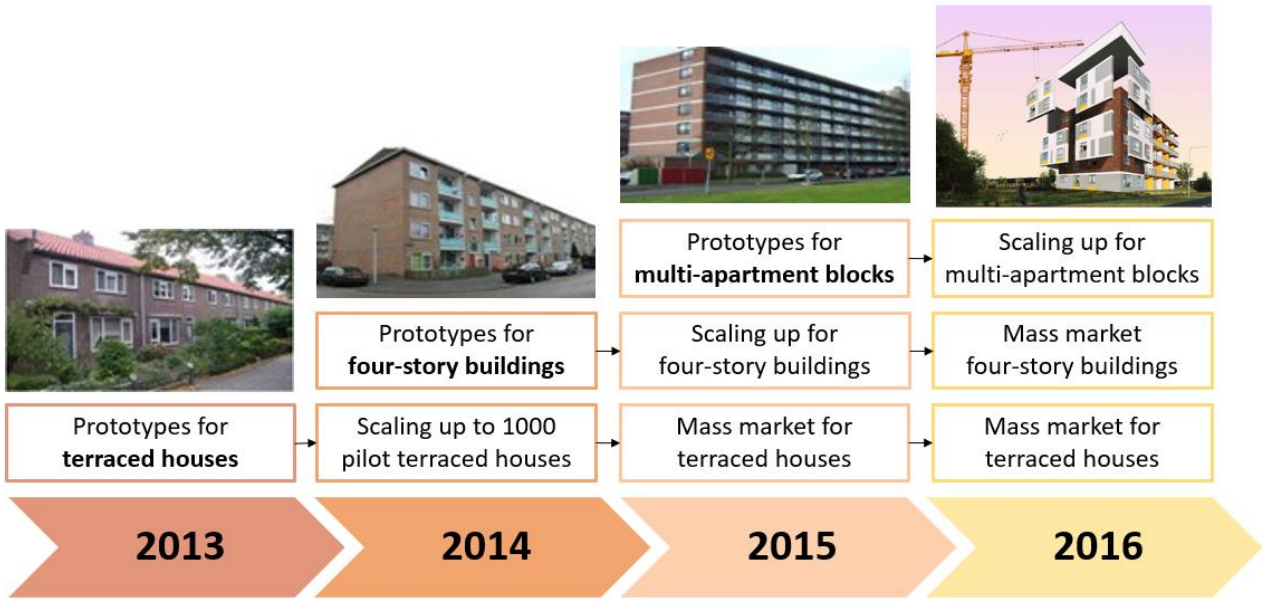


Figure 12 *Energiesprong scale up strategy in the Netherlands*

Dutch government funding ended in 2016 but additional economic support to the whole Energiesprong network has been obtained through three EU research projects which have been described in paragraph 2.3.1 as part of the state-of-art analysis. A total of **€ 20.6 million** have been allocated among 5 different Countries as follow:

- From 2016 to 2019 **Transition Zero**, a Horizon 2020 project, received € 3.6 million shared between Netherlands, France and United Kingdom partners (EU Horizon 2020 project TRANSITION ZERO, 2018);
- From 2016 to 2019 **E=0**, a Interreg North-West Europe project, received € 5.4 million shared between Netherlands, France, United Kingdom and Luxembourg partners (EU Interreg NWE project E=0, 2020);
- From 2019 to 2022 **Mustbe0**, a Interreg North-West Europe project, received € 11.6 million shared between Netherlands, France, United Kingdom and Germany partners (EU Interreg NWE project MustBe0, 2023).

Besides the EU subsidy programs, Stroomversnelling is funded by all its members (institutions, housing associations, solution providers) and by the European Climate Foundation, a philanthropic fundraising initiative to foster the development of a net-zero emissions society.

To date**, 5.700 houses have been retrofitted and 14.400 are on the pipeline**. Stroomversnelling suppliers are developing the first NZE concepts for apartment buildings of more than 5 stories which are mainly privately owned in the Netherlands. Therefore, next to technical innovation, the market development team is focusing on finding proper financial solutions for private owners willing to invest in Net Zero Energy refurbishments.

In addition, being the most advanced Energiesprong country **it has already monitored several houses** on execution, delivery and usage. In particular, the monitoring of 46 homes in Heerhugowaard and 18 in Tilburg, shows that on average the actual energy performances match the design specifications, meaning that the guarantees are respected (Energiesprong, 2019). Space heating usage solar production have been a little more than expected. In some cases, among early projects there has been insufficient air tightness due to some problems with the panels' installation and also bad quality products of one specific company. Such issues are inevitable in the first interventions, but monitoring is crucial to quickly address the problem ad improved the upcoming design. It was also helpful to spot too high consumptions among occupants who were consequently educated to avoid higher energy bills. In addition, several aspects of tenant satisfaction were measured: they were generally satisfied with the retrofit result but less happy about the overall process. These first monitored projects explicated the need to incorporate occupants wish in the intervention, clearly communicate with them and properly manage their expectations.

Energiesprong key success is the interest it has generated globally which is contributing to create synergies and scale the process. Indeed, activating the industry on an international level drives competition in the development of innovative and cost-optimal solutions to make NZE retrofits a market reality in the long-term.

4.2.2 France

In France social housing is connected to the concept of low rent housing, the so-called **Habitation à Loyer Modéré (HLM)** and it represents the 17% of the total housing stock with 5.2 million dwellings being the 42% of all the rental ones. It is a specific sector of the housing market, which is governed by legislative and regulatory provisions, separate from common law, and regulated by the Construction and Housing Code (Le Code de la Construction et de l'Habitation, CCH).

Who provides social housing?

In France social housing is mainly provided by 'HLM' organisations, which are specific actors entrusted and supported by the state to fulfil a mission of general interest. The provision of social housing includes construction, development, allocation, and management of rented social housing as well as of dwellings for social home ownership. HLM organisations include both publicly and privately owned companies acting on a limited profit (4 per cent return) basis and under the control of the Ministry of Housing and Finance. They are grouped under the **Union sociale pour l'habitat (USH)** which gathers five federations:

- **Offices publics de l'habitat (OPH)**, 260 public entities having around 2 million of social dwellings;
- **Entreprises sociale pour l'habitat (ESH)** 240 private limited companies having around 2 million of social dwellings;
- **Sociétés coopératives d'HLM,** 173 cooperatives having more than 300.000 social dwellings;

- **Sociétés anonymes coopératives d'intérêt collectif pour l'accession à la propriété (SACICAP),** 52 social housing organizations and financial companies charged by the State to promote accessible home ownership;
- **Associations régionales d'organismes d'habitat social (FNAR),** 12 regional associations grouping together HLM territorial entities.

To a lesser extent, there are also other providers: semi-public enterprises (**Société d'économie mixte, SEM**) and some non-profit associations. SEM are public limited companies whose shareholders are the territorial bodies with a minor participation of private or public partners. They are subject to the private law, but they benefit from an exceptional ruling that is justified by the general interest character of their missions and by their predominantly public shareholders. For this reason, financial aids are open to them under the same conditions as those applied for HLM organisations. The local SEMs should be distinguished from the State SEMs which are established between the State and private shareholders with a minor participation, if any, of local bodies if they are participating at all. There is only one State SEMs related to the housing world: **CDC Habitat** (previously Société nationale immobilière, SNI) which is a subsidiary of the Caisse des dépôts et consignations, whose main mission is the management of public real estate assets. As part of CDC Habitat group, ADOMA has been created to accommodate migrant workers and it manages around 200.000 social housing units.

Who can access social housing?

Access to social housing is limited by **income ceilings**, which are set at the national level by specific regulation and vary according to the area were the dwelling is located as well as the number of household's components. Even though ceilings are set to allow a certain degree of socio-economic mix, almost half of HLM households has an income below the poverty line. Furthermore, priority access is given to the following categories: homeless; people at risk of eviction who don't have the possibility of finding another accommodation; people with temporary accommodation; persons in unhealthy or unfit accommodation; households with children in overcrowded or indecent dwellings; disabled. Immigrants and other ethnic-minority groups comprise a significant proportion of tenants in social housing. Also elderly people are increasing rapidly.

How is social housing financed?

Rents are based on the net construction cost, which is lowered by two main stabilizing elements:

- **state and local subsidies** (typically around the 11% of the financing scheme for an average flat rented) and local tax exemptions;
- **housing benefits** that ensure that the poorest households are able to pay the rent (one household out of two receives them in the rental social sector). They also cover, on a flat rate, common area expenditures (which are invoiced separately).

On the other hand, if a household's income increases to the point that it exceeds the income ceiling, rents rise accordingly (less than 10% of social tenants are concerned).

The provider establishes the rent required to balance the operation income and expenditure account during the life of the building or at least throughout the main loan, that is to say for a period of 40 years.

Most of the funding for new construction comes from **finance loans, where the main lender is the Caisse des Dépôts et Consignations (CDC) which provides funds from the 'Livret A' accounts**, covering the 76,5% of financing scheme. Livret A is a tax-free savings fund with regulated interest rate, guaranteed by the State. Every French household has the right to open a tax free Livret A Savings Account at the local bank. Such savings are, then, pooled by the CDC, which pays a fee for the funds collection and a defined interest rate to the banks. In these loans, there is no premium offered since they are available at cost price (i.e. the interest paid by the social housing provider equals the interest rate plus the cost of collection paid by CDC to the banks). The advantage is the transformation of very liquid savings into very long-term loans (up to 60 years). The key issue with this mechanism is finding the appropriate rate to raise the necessary level of savings while not paying too much interest, and thus provide cheap funding to HLM companies. The French **saving scheme model** can be considered an example of State guarantee that has secured finance of social housing even at

times of crisis. Indeed, off market loans financed by a protected savings circuit have ensured that a sustained range of housing programs have been able to deliver dwellings for a variety of income levels.

Other sources of financing include:

- **employers' grants and discounted loans** (the so called '1% Logement', the 1% tax on salary which was designed to promote housing for employees, recently decrease to 0,45%). It typically covers the 2,5% financing for an average flat rented. The service is currently managed by Action Logement which ensure the aids distribution.
- **guarantees from local authorities or the HLM guarantee fund (CGLLS)** w which shows engagement in restructuring the weakest housing companies.

The remaining 10% of financing comes from equity capital. In addition, a number of **tax provisions** promote lower social housing costs. These include:

- exoneration from land tax for a period of 25 years (instead of two years for nonsubsidised housing).
- Exoneration from profit tax due to their public service role. Corporation tax is due on the other activities.
- Reduced rate of VAT, meaning a lower sales tax for social housing construction.

How is social housing traditional renovation organized?

In France the average dwelling size is 66 m². Peak construction of social housing was recorded in 1960s and 1970s, with the first regulation for energetic performance dating back to 1974. Average social housing dwelling is today 37 years old, and although the country has been quite active in renovation, there is still a real need for energetic retrofitting of social dwellings. This has been acknowledged by the creation of a dedicated loan (called « ecoloan ») by the bank Caisse des Dépôts in 2009. **The 46% of the stock is tagged A,B or C, while a 36% is rated in class D and the 18% in E, F, G.** The most common energy source is gas (around 55%) both in collective (85% of the stock) and individual (the remaining 15%) dwellings, followed by electricity and district heating (about 20% each).
The financing for energetic retrofitting in France relies on several tools:

- **Eco-loan** (éco-prêt logement social) that is a loan in the amount of €6,500 (for minimum primary energy gains, around 100 kwh/m²/year) to €33,000 (in case of guaranteed neutral energy projects, above 390 kwh/m²/year gained) per dwelling, accessible to social landlords, for the rehabilitation of the most energy-intensive social housing. It is intended to finance the renovation of the stock whose energy and climate performance corresponds to classes D, E, F or G of the energy performance diagnosis. It is given by Caisse des Dépôts to those dwellings eligible for housing benefits, it follows a reduced Livret A variable interest rate, and it accounts for the 43% financing of the whole retrofit.
- To be able to benefit from the loan, the borrowing organization must justify an energy gain of 40% minimum or 80 kwh/m²/year minimum, and a label A, B, C, or D after works (consumption less than 250 kWh/m²/year). The eco-loan can support experimental rehabilitation approaches to achieve ambitious energy and/or carbon performance. In particular, it can be increased by €3,000 per dwelling if a reduction in greenhouse gas emissions of at least 70% occurs and the gas heating system is replaced.
- **Improvement loan**, which is designed for general maintenance since energy retrofitting is frequently done in conjunction with other works. It is also given by Caisse des Dépôts to those dwellings eligible for housing benefits, it follows an augmented Livret A variable interest rate, and it accounts for the 19% financing of the whole retrofit.
- **Loans from employers' contribution** (Action Logement) are also available, but they just amount for the 1,5% of financing, while generic commercial loans reach the 4,5%. It's worth noticing that these averages do not reflect reality. Most renovations have none of these loans while a small number do with higher amounts.
- **Subsidies** coming from the State (mainly the urban renewal agency), regional or local authorities, the European funds (ERDF, Recovery Plan and so on) and the national agency for environment and energy

management (ADEME) which helps the development of renewable energies. In total subsidies represent the 20% of the financing plan.
- **Own funds** (11% of financing), which are usually not recouped but they should be linked to higher value of the dwelling once retrofitted.
- Bonds or securities on the financial market and loans form the European Investment Bank are not used.

Looking at the cash flows throughout the years, soft loans are usually guaranteed by local authorities for free and they have a maximum length of 25 or 35 years maximum with an annual reimbursement as main outflow. Inflows come from:

- **Reduced VAT rate** at 5,5% which concerns all types of works (not only energetic one) and **land property tax deduction** for up to 25% of the amount of retrofit works.
- **White certificates trading scheme** which can be sold to energy sector companies that are obliged to buy a certain amount by law.
- **creation of a «third line»** dedicated to renovation, paid by tenants above rent, common area expenditures and service fees. Few providers have used it since occupants must approve both the works and their contribution, showing little enthusiasm for it.
- **Rent increase** up to 10% after works, within the limit of the ceiling, but usually it doesn't exceed the 3%. It last as long as the dwelling is used, which is often longer than underlying loans, thus generating cashflow afterwards. Rents should be computed to cover loans reimbursement, annual expenditure on repair and maintenance, management costs and taxes but most energetic retrofits report a clear disequilibrium with outflows being higher than inflows.

What are the main policy developments and trends towards renovation?

Social housing standards have improved significantly since the mid-1980s, implying large scale public expenditure on refurbishment, which has never stopped since then:

- The government decided to regenerate social housing further in **2000** as part the Law 2000-1028 on Solidarity and Urban Renewal (Loi SRU).
- In **2006** another programme was established to demolish and replace 250.000 of the worst social housing and to renovate another 400.000 units. This and other programs were managed by a new urban renovation agency (ANRU- Agence Nationale de Rénovation Urbaine) with the goal to create a greater social mix and to increase the participation of the inhabitants in the associated renewal projects.
- Further on, under the so called "Grenelle de l'Environnement", HLM's have been engaged in a plan to renovate by 2020, 800.000 social housing units to improve their energy efficiency, using the EU support through the ERDF.
- In **2015** the French Parliament adopted an overarching legislation aiming at boosting the energy transition, involving also the social sector. In particular, it imposed the renovation of 250.000 low-income dwellings from 2017, focusing on those rating F and G which should be all improved by 2025; the annual retrofit of 70000 social rental houses with ecological loans from Caisse des Dépôts; the reinforcement of the requirements related to renovation to bring performances closer to the one of newly built homes.
- In November **2018**, a new Law on housing, urbanism and digitalisation (ELAN) was adopted. Among others, it included measures for the revitalization of city centres and energy refurbishments. It has been followed by the Major Investment Plan (Grand Plan d'Investissement) with the objective of 125.000 annual social housing renovations for energy savings of at least 1 label.
- Currently, key to the future sustainability of the sector is the funding of a stability enabling HLM companies to keep their investment capacity also for renovation, which remains a priority, as highlighted by the EC 2019 Country-Specific Recommendations. Access to European funding can still complement available resources and have a significant impact.

- The French government has put tackling climate change at the heart of its pandemic **Recovery Plan (Plan de relance**), earmarking €500 million to social providers for the renovation of their stock. Funds have the goal to allow for the renovation of 40,000 social dwellings, in addition to the financing that Action Logement is providing to intervene on further 60,000 low-income homes (Ministère de l'économie des finances et de la souveraineté industrielle et numérique, 2021).
- As part of the € 500 million, € 40 million has been explicitly addressed to the **MAssiRenò programme** by the Ministry of Ecological Transition to help develop increased capacity for cost-effective social retrofits over the long-term. The approach to be adopted is based on guaranteed performance contracts and economically sustainable solutions with potential for innovation and industrialisation (already experienced through Energiesprong).
- Following the adoption of the **Loi Climat et Résilience** (Climate and Resilience Law - August 2021), **all landlords, including social ones, in France must renovate housing units that fall within the E, F, G categories by 2034 or they will no longer be allowed to rent them out.** USH estimated that about 1.8 milion housing units have to be refurbished, implying an investment of € 7.5 billion a year (Ministère de la Transition écologique, 2021).

What are the main Energiesprong highlights?

Implementation date	2016 – on going
Market development team	Greenflex, sustainability consultancy company
Funding structure	3.6 million shared (transition Zero, H2020 2016-2019) 5.4 million shared (E=0, Interreg, 2016-2019) 11.6 million shared (Mustbe0, Interreg, 2019-2022) ADEME, the French Environment and Energy Efficiency Agency. Caisse des Dépôts
Achieved results	1250 retrofitted houses
Expected results	6550 planned retrofits

In **March 2016**, Energiesprong was launched in France, together with the beginning of **Transition Zero and E=0** projects which have, among others, the objective to create early markets for net zero energy refurbishments using frontrunner social housing organizations in France and United Kingdom. The market development team is hosted by **GreenFlex,** a sustainability consultancy company specialised in helping organisations to accelerate their social and environmental transition. GreenFlex has set up a market development team of 7 people to adapt and implement the Energiesprong approach with local stakeholders (Energiesprong FR, 2023a).

The first two project renovated, funded by E=0 project, are 10 houses in Hem (housing provider: Vilogia, general contractor: Rabot Dutilleul Construction, intervention: from class F to class A spending € 1.200.000) and 12 units in Longueau (housing provider: ICF Habitat, general contractor: Bouygues, intervention: from class F to class A spending € 1.500.000) (EU Interreg NWE project E=0, 2020).
These first demonstrators have inspired others, within the MustBeZero project and beyond: 64 stakeholders, among which 14 housing associations, have signed a charter engaging them to contribute to the Energiesprong dynamics in France. Financing has been obtained also from ADEME (The French Environment and Energy Efficiency Agency) and Caisse des Dépôts, which plays a major role in financing social housing, energy transition and smart city developments.

Particularly relevant, is the **renovation of 988 residential units**, spread over 9 buildings having 11 floor each, commissioned by Est Métropole Habitat near Lyon in 2020 (see **Figure 13**). The panels on the east façade were installed in just 8 days using the crane without the support of scaffoldings, showing the feasibility of industrialized interventions on multi-storey apartment buildings (Energiesprong FR, 2023c).

Figure 13 *Installation of industrialized panels for the social building owned by Est Métropole Habitat near Lyon*

Beside scattered project, the recently born **MASH ((Mutualisation d'Achat au Service de l'Habitat)** initiative represents the **first purchasing centre for industrialized and guaranteed zero-energy renovations** and it was driven by the Social Union for Housing in Pays de la Loire. It promotes the pooling of purchases and the coordination of actors, thank to which social landlords can carry out large-scale renovations and achieve ambitious objectives in terms of energy efficiency. For the first time, 14 social landlords have come together within a central purchasing body to launch a group order for Energiesprong renovations addressing approximately 2,000 homes. The units have been divided into 5 lots of a few hundred units each. The renovation works will take place in a staggered and progressive manner, allowing all companies, whether small or large, to participate to these first aggregated call for tenders (Energiesprong FR, 2023b).

To conclude, Energiesprong France has put a lot of effort in monitoring and analysing the market development to redact the first **Observatory of Costs, Quality and Impact of Energiesprong renovations** aimed at establishing trajectories based on project data (Energiesprong FR, 2021). Six major housing types have been identified for mass industrialized renovation, starting from 22 typologies (characterized by different construction periods and different geographical locations. There are 3 categories of detached houses and 3 of multi-family buildings, for a total of 14 million units suitable for interventions. In addition, for each of the dimension analysed has compared Energiesprong renovation with 3 other scenarios: minimum maintenance, traditional renovation, and demolition/new construction. The main fundings are summarized below:

- Prices are already falling, with a -20% reduction for current projects compared to the first projects.
- Observatory data can be used to draft the price trajectory and assess likely prices for mass markets. Single family housing retrofits will cost around €900 /m^2 VAT excluded (-40% compared with initial projects), while multi-family housing will be about €700 /m^2 VAT excluded (-55% compared with initial projects).
- In terms of overall cost over 30 years, Energiesprong offers the best performance/cost ratio compared with the other scenarios.

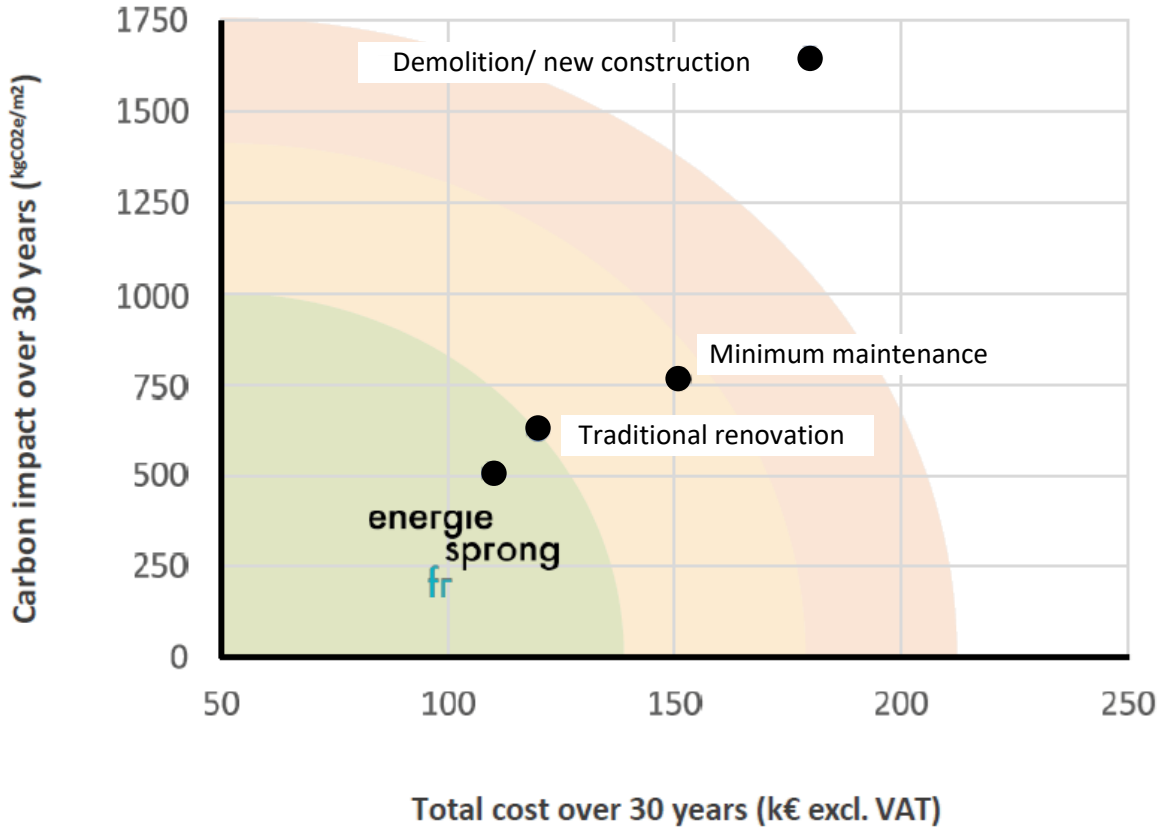
QUALITY

- The solutions implemented on the pilot projects enabled to achieve and even surpass the goal of zero energy for all uses (production > consumption).
- Heating requirements are reduced by 75% compared with the existing system.
- Numerous high-performance solutions are emerging. They present common features such as the use of integrated and prefabricated solutions and a growing share of bio-sourced materials.

IMPACT

- Compared with the other scenarios the carbon impact of an Energiesprong renovation is the lowest, in both multi-family and single-family housing.
- An Energiesprong intervention reduces the total carbon impact of a home over 30 years by 35% (considering all greenhouse gas emissions and not just those associated with energy consumption), compared with a minimum maintenance scenario.
- This reduction can reach 50% when the most carbon-free constructive solutions are implemented (such as bio-sourced prefabricated facades and roofs). Instead, it goes up to
- For E, F or G homes, decrease in carbon impact can get to 75%, two times better than a traditional renovation.

Considering an average social housing stock, the advantages of Energiesprong renovations in terms of overall cost and carbon impact over 30 years, with respect to the other scenarios are aggregated in **Graph 2**.



Graph 2 *Total cost and carbon impact over 30 years: comparison among different retrofit approaches*

4.2.3 United Kingdom (England)

Due to the United Kingdom withdrawal from the European Union in 2020, Housing Europe stopped its reporting, providing fewer data on single Countries only. The focus of the thesis will be on **England**, since it's where Energiesprong initiative took place. S**ocial housing accounts for 17% (4.000.000 dwellings) of the total homes in England**, one of the highest shares in Europe. Social housing in the UK is as intended low-cost housing allocated on the basis of need and it includes the provision of rental dwellings, affordable home ownership, as well as shared ownership schemes.

Who provides social housing?

Historically, local authorities would have delivered social housing but now the majority is provided by **Housing Associations (HAs),** as a reflection of significant stock transfers since the **Housing Act 1988**. Indeed, between 1979 and 2006, 1.600.000 local authority dwellings were sold through the Right to Buy to sitting tenants. The **Right To Buy** scheme allowed occupants to buy their home with a discount of 33–50% off the market value, depending on the time they had lived there.

Housing Associations include cooperatives, not-for-profit entities and trusts, they vary significantly in size and they are mostly grouped under the England National Housing Federation (NHF). In addition, there are also a few independent public bodies and private for-profit developers but just within certain funding schemes. The social housing sector is divided as follows: 2.479.000 dwellings are managed by HAs while 1.587.000 council homes are managed by local authorities, directly or through **ALMOs (arm's-length management organisations)**, grouped in the NFA (National Federation of ALMOs).
Housing Associations in England are regulated by Homes England, a non-departmental public body that replaced the Homes and Communities Agency (HCA) in 2018. HCA in turn was established in 2008, joining together Housing Corporation, an executive agency for new affordable housing and English Partnerships, the national regeneration agency, having in this way both investment and regulation functions.

Who can access social housing?

General criteria for access to social housing are established by law at national level but **local authorities have significant discretion to formulate their own criteria to determine who may qualify for social housing in their areas, since the Localism Act of 2011.** Housing associations have the power set their own policies on what criteria they apply to selecting tenants, but local authorities actually decide about the 75% of them.
Social housing target groups range from lowest income households to intermediate middle class households. Even if most of the population is virtually eligible for social housing, allocations are predominantly needs-based with priority given to homeless, vulnerable people and occupants dependent on benefits. A particular feature is the choice-based lettings system: available housing associations' units are advertised, and prospective tenants can bid for the property the like, giving greater stability to HAs.

How is social housing financed?

In the case of social housing owned by housing associations, the provision of new housing are mainly financed through three funding sources:

- **housing association's reserves** (obtained also by a range of different services and activities carried out);
- **government grants**, coordinate by Homes England;
- **private finance** consisting of bank loans or funding raised on the capital markets, through bonds. The conditions vary significantly among the HAs, with some of them being rated AA2 by Moodys[19] (by the level of implicit public sector support);

[19] Moody's, is the bond credit rating business of Moody's Corporation, Along with Standard & Poor's and Fitch Group, it is considered one of the Big Three credit rating agencies. The company ranks the creditworthiness of borrowers using a standardized ratings scale which measures expected investor loss in the event of default. Aaa is highest quality and C the lowest one. See: https://www.moodys.com/

- **cross subsiding new development from low-cost home ownership properties** (but mainly before the 2008 crisis).

One measure of the success of the sector, in PPP terms, is the fact that in England significant private finance from the banking and capital markets has been committed to housing associations, exceeding public sector grants. In particular, the **issuing of bonds** is well seen, since HAs own long-term assets with stable cash flows so the risk exposure is limited.
Furthermore, social housing also benefits from discounted land and development contributions under **"section 106" provisions**. In this case when granting buildings planning permission, local authorities can ask private developers to enter into a voluntary legal agreement (known as Section 106) that obliges them to allocate a fixed proportion of homes as affordable homes. In most cases, these homes will be sold to a housing association at a discounted price.

From a **fiscal point of view**, there is no VAT on new build, but there is on repairs. Social housing is exempted from the Community Infrastructure Levy on new developments, but it must pay the land tax.
Tenants in social rented homes pay a weekly rent which is well below market level (currently around 40 to 60%). When talking about affordable rent, instead, the amount is up 80% of market rent and the lease contract is limited in time. Depending on their specific contract with the regulatory body, housing associations can decide to convert a proportion of their existing social rent stock into affordable rent to reinvest the income in the supply of new housing.
In addition, **housing benefits** are an important feature of the social housing (and private) system in England. The amount a person receives will depend on income and specific personal circumstances.
In conclusion, the balance between supply side and demand side subsidies has changed significantly over recent decades in favour of the latter.

How is social housing traditional renovation organized?

England's housing stock is among the oldest in Europe with the social sector being, on average, much newer (especially homes built by housing associations with respect to local authorities): almost the 40% has been built between 1945 and 1980. The average social dwelling size is 67 m2 and it is more efficient than the private English stock. **Around 45% of units are in class D and as many in class C. However, the 10% rated between E and G have a high incidence** of property characteristics that are typically difficult to treat. More than 9 out of 10 households in England have central heating with individual invoicing. The most common fuel type is gas.
Housing associations usually take a strategic approach to investment in their stock, concentrating on the worst properties first, to gradually reach the minimum energy standard requirement imposed by the law.
In general, housing refurbishment are financed by different components:

- **own capital made of rental income**, reserves and, in some minor cases, sale of extra flats constructed during the renovation phase;
- **subsidies** from local authorities and grants from the government;
- **bank loans and bond finance**, used just for major cyclical investments in energy efficiency programs, without dedicated discounts on interest rates.
- **energy savings certificates** delivered in the framework of the Carbon Emission Reduction target. The most used is the national supplier obligation scheme called **Energy Company Obligation (ECO).** It is funded by the energy suppliers through a levy on household energy bills and it finances all kind of energy efficiency works (insulation, heating improvements, some renewable energy measures). Every ECO phase sets a subsidy available per ton of carbon saved. It is targeted at low-income households and the least energy efficient properties. All E-G rated social housing properties are automatically eligible for funding. Energy suppliers are required to inspect on ECO measures to ensure the required standards of installation are met but there is no ongoing monitoring required from housing providers once works are completed. For this and other reasons, even if ECO has supported significant improvements, it does not promote disruptive innovation.

Energy retrofitting does not benefit from tax discounts, except a reduced VAT in case particular materials or technical systems are installed. The national rent setting standard prevents social landlords from charging higher rents for more energy efficient properties and energy savings cannot be recouped from tenants, who are usually responsible for their own electricity, heating and water bills through direct contracts with suppliers. On the other hand, social housing providers can receive payment from the government over a 7- or 20-year period for the generation of renewable heat through the Renewable Heat Incentive and for the generation of electricity through the Feed in Tariff. Both schemes provide some level of financial support to housing providers to improve building energy performance and they require ongoing metering of energy generated.

Overall, the average performance rating of social housing has increased over time, but highly efficient retrofit programs still struggle to deliver improvements at a manageable cost.

What are the main policy developments and trends towards renovation?

The Hills Review on the role of social housing, published in February 2007, found that social housing has improved in many areas particularly in terms of stock condition and affordability, but there are still significant areas of concern that need to be addressed and more attention should be paid to the existing social housing stock.

In the last decades, housing associations are investing heavily in building, regenerating and delivering wide ranging local services with the aim is to promote neighbourhoods where there is a place for everyone.

Homes England is being created to work to: increase the supply of housing (including affordable housing for rent and shared ownership and low-cost home ownership), regenerate underperforming urban centres, transform disadvantaged estates through promoting mixed communities, promote more effective use of public sector assets, innovate to improve efficiency, increase investment in housing and urban regeneration and drive the adoption of high environmental standards.

The renovation of social homes is also on the agenda. This includes a new £ 50 million pilot social housing retrofit programme. In addition, as part of an effort to make homes greener and warmer, £ 60 million of extra funding to support renovations in the social housing sector has been allocated for 2021 financial year.

In England, **from 2020 private homes can only be rented out if they are in class E or higher. From 2025 the limit is restricted to class C, while property owners and social housing organisations have until 2035.**

In 2023, the UK government is allocating dedicated funding (£1.4 billion) to local authorities, providers of social housing and charities to subsidize energy-efficient home retrofits, with a focus on social housing, through both its Home Upgrade Grant scheme and the **Social Housing Decarbonisation Fund (SHDF**). The money will go towards improvements to vulnerable households with an EPC rating of D or below. Energy cutting and cost saving measures provided through the schemes include exterior wall insulation, cavity wall insulation, loft insulation, new windows and doors and draft proofing measures, as well as heat pumps and solar panel installation (International Energy Agency, 2023).

In addition, the **social housing retrofit accelerator (SHRA)** has been parallelly created and is funded by the Department for Energy Security and Net Zero. It consists in a support service to help social housing providers across England successfully bid into the Government's Social Housing Decarbonisation Fund (SHDF), with £800m committed until 2025. The goal is overcoming the barriers to developing retrofit projects, which are not only financial but also linked to technical and bid management topics (Government of the United Kingdom, 2023).

What are the main Energiesprong highlights?

Implementation date	2016 - on going
Market development team	Energiesprong UK, network of 14 founding partners
Funding structure	3.6 million shared (transition Zero, H2020 2016-2019) 5.4 million shared (E=0, Interreg, 2016-2019) 11.6 million shared (Mustbe0, Interreg, 2019-2022) Founding partners, both housing associations and solution providers
Achieved results	130 retrofitted houses
Expected results	1500 planned retrofits

Energiesprong UK is an independent market development team with 14 founding partners who are frontrunners in the field of sustainability and innovation from the social housing sector as well as construction companies that share the vision of working together to innovate the sector. In addition, it has a range of supporting partners that are relevant stakeholders in the transformation Energiesprong UK is aiming to achieve. Beside the funding received by the EU projects, it is financed by the founding partners (housing associations and solution providers) (Energiesprong UK, 2023).

Figure 14 *Nottingham single family houses after a Energiesprong renovation*

Within the framework of **E = 0 Interreg project** (EU Interreg NWE project E=0, 2020), two pilot projects have been delivered, both targeting single family houses:

- **In Maldon** a 5-house pilot was delivered by ENGIE (solution provider) and GSA (architect) with Moat being the housing provider. The goal was to reduce the level of carbon dioxide per house by 3.2 tonnes per year, starting from a D rating. The main challenge was that the local planning office required the street scene to remain unchanged so, apart from the addition of solar, original looks needed to be preserved. To do so, ENGIE opted for acrylic brick-effect external insulation panels, which were colour-matched to the brickwork they cover. Tenant engagement was also key for the success of the project. Tenants have been consulted throughout the process, including weekly progress meetings, training sessions and manuals to show how to use the new technologies installed.
- **In Nottingham** 17 homes, comprising of 10 bungalows and 7 two-bedroom, three-storey houses, have been improved (see **Figure 14** Nottingham single family houses after a Energiesprong renovation**Figure 14**). They are owned by Nottingham City Homes ALMO and have been retrofitted by Melius Home.

Their predecessor was the 10-home pilot project delivered by Melius Homes, designed by Studio Partington and funded by the Horizon 2020 Transition Zero projects. It won the UK Housing Award for Innovation in recognition of Nottingham City Homes' pioneering approach to tackling energy inefficiency in older housing stock to address both climate change and fuel poverty. The positive impacts, the tenants' satisfaction and the potential to regenerate the neighbourhood led Nottingham Councillors to support the upgrading of up to 155 homes in 2019. Therefore, the ALMO has secured over £5 million through the European Regional Development Fund with its Deep Retrofit Energy Model project, to support this rollout.

Under **MustBe0 Interreg project**, the focus has been shifted to multi-storey buildings pilot projects, tackling in particular: 24 units in a 2-storey building in the London Borough of Ealing and a 5-storey apartment block of 38 flats in North Kensington, London (EU Interreg NWE project MustBe0, 2023).

Beside the demonstrators, a **MustBe0 competition was launched in 2020** by Energiesprong UK to to develop new approaches for high-performance, scalable and cost-effective net zero retrofit solutions focused on apartment blocks. There were three categories to focus on: adding a layer of new dwellings on top of existing flats while ensuring whole building net zero energy, Net zero energy for low rise apartments (< 4 stories), and billing, metering and monitoring. In 2022, instead, a second design competition was launched, making £40.000 available for panel manufacturers and suppliers to propose offsite multi-storey fabric systems that are nearing market readiness. Competitions have been tested across different Energiesprong countries, as an effective way to collect and compare innovative solutions under development.

In conclusion, Energiesprong UK is also delivery partner (together with Turner and Townsend) of the £ 10 bn **The Retrofit Accelerator-Homes Innovation Partnership,** which is a new way to approach retrofit procurement, all across UK (Energiesprong UK, 2022). Indeed, in England several housing associations are public, so finding effective tendering procedures in key to the scalability of Energiesprong market. The Retrofit Accelerator - Homes programme is funded on a 50:50 basis by the Mayor of London and the European Regional Development Fund (ERDF). Within the partnership, seven London-based social housing providers and four UK building firms, along with a network of suppliers, are working together to stimulate a new market for whole house retrofit and reduce costs. The ultimate goal, after the three-year Innovation Partnership, is the creation of a national framework agreement for delivering retrofit projects and exploit the Social Housing Decarbonisation Fund (SHDF). In fact, paring social landlords with solution Providers (who are responsible for design, delivery, guaranteed performance, and in some cases maintenance), provides a runway to develop new net-zero components targeted to hit specific performance standards. In pilot projects it has been noted that procurement required suppliers to put a lot of design work, often in a short time frame. For this reason, to foster research and development, in the Innovation Partnership, bidders will receive £30.000 for the design stage to contribute towards costs. The main strength of the approach is that suppliers do not compete each other: if they create a solution that works within the gross maximum price, the potential market is so big that they can deliver prototypes, pilots and finally they get a spot on the national framework, which enables any UK housing provider to purchase their solutions.

4.2.4 Germany

In the country social housing represents **4% of the total housing stock (around 1.700.000 dwellings)** and is declining gradually. The right of municipalities to allocate dwellings to the neediest households does not translate any longer into the construction of new social dwellings. Therefore, the system for social provision of housing is based on allocating dwellings from the existing rental stock, on a case-by-case basis, through a temporary convention between the municipality and the landlord, which sets the rent at a price lower than the market for people who cannot afford a dwelling otherwise. For this reason, in Germany **the term "social housing" is rarely used**, and legal texts generally refer to "publicly subsidised housing" or "social housing promotion" (Wohnraumförderung), meaning housing which is built using state financial supports, in return for which the owners must provide a legally defined sub-market rent to low and moderate income households. When the state financial supports are amortized (typically 30 years for newly built units with public subsidies, and 15 years for renovated ones), the dwelling ceases to be legally defined "social" and the owner can rent it at a private market price. However, then the owner is a cooperative or a municipal housing company, in practice the dwellings continue to be rented out at affordable rates. There are currently close to 4 million of such residential units in Germany, thus, it's reasonable to state that there is an overall affordable stock of **more than 5 million homes, exceeding the 10% of the whole housing sector**. The reason why they are not officially counted within the social housing stock is due to the lack of reliable figures for this portion of the sector since, once out of the "lock-in" period, anyone can theoretically apply to live in municipal or cooperative housing and it is up to providers to manage such requests.

Who provides social housing?

The Federal association of German housing and Real Estate Companies (GdW - Bundesverband deutscher Wohnungsund Immobilienunternehmen) encompasses almost the entire social housing sector, with about 1.2 million social rental units out of 6.000.000. The remaining 500.000 (constituting the traditional non-profit sector) are managed by housing cooperatives, organisations owned by churches and municipal housing companies. The institutional non-profit sector was dissolved in 1989 and the extensive assets owned by municipalities have been more and more privatized leaving the floor to companies belonging to national and foreign investment funds. These are grouped in regional federations, which are in turn members of the national umbrella organization, the GdW. Overall, public intervention in housing policy in Germany is not linked to specific providers but entails public subsidies of any kind of housing providers in exchange for the use of a dwelling for social purposes on a temporary basis. Even so, many cities still have at least one publicly owned property company providing housing. Independent private rental companies, landlords, and commercial developers with a variety of shareholders are also part of the providers.

Who can access social housing?

The target groups are defined by the legislation as **households who cannot secure themselves with an adequate accommodation and need support.** The policy supports low-income households as well as families and other households with children, single parents, pregnant women, elderly, homeless and other needy persons. Local authorities are in charge of ensuring affordable accommodation, while the federal state remains responsible for housing allowances to individual households and rent regulation. Indeed, access to social housing requires a certificate of eligibility to public housing issued by municipal authorities and income ceilings are applied.

How is social housing financed?

From a legal point of view, all housing companies are considered market actors, although municipal housing companies act according to local policies. Since 2007, social housing is entirely a **competence of the Länder (federal states)**, which have applied different programmes and funding schemes, while the federal government (Bund) has withdrawn to provide a framework-legislation only. Within the general rules

stipulated by the Federal Act, the rules of assistance differ widely amongst the various Länders, whereas it is the municipalities themselves who actually implement decisions.

Currently social housing funding arrangements vary significantly across the different Länder so it is very difficult to give a comprehensive picture of the financial mechanisms. When available, public support for the provision of social housing can take the following forms:

- **Loans with attractive conditions** (the reduction of interest rates or reduction of repayment rates);
- **Public subsidies** (grants) to cover the gap between the perceived rent and cost rent. They are open to everyone, meaning that companies as well as private individuals can apply, if respecting occupancy and rent control rules;
- **Take-over of liabilities** to secure demand of third parties;
- **Tax concessions** to promote private investment in social housing.

Most recently housing policy in Germany has shown a significant shift towards demand assistance strategies and stronger caps on rent increases, together with a decline in bricks and mortar subsidies and a withdrawn from direct supply support. **Housing allowances and regressive tax rebates** are available for people below certain income ceilings, notwithstanding whether they rent or own their house. However, the potential impact of tightening rent price regulation is a matter of debate, with GdW warning that it risks counteract efforts to stimulate construction.

How is social housing traditional renovation organized?

Dwellings managed by housing companies members of GdW have an typical living space of 61.42 m². They are almost all built before 1990, while the 60% was already constructed in 1960. GdW rental apartments, including the majority of social stock, are more energy efficient than the average: **the 15,6% has a F, G, H rating, the 40% E and D, the 21% is in class C and the 23,4 % reaches A and B.** Half of the dwellings have district heating, with a 30% coming from renewable sources. Adding heat pumps and biomass the whole renewable share touches the 20%.

Around the 2% of the stock is improved annually, meaning 130.000 units a year, but only 36.000 undergo a fully energetic renovation. **Since 1990, 42 % of GdW housing has been fully modernized**, being above the European average. However, even if the pace should be kept or even improved to reach the 2050 targets, the risk is to slow down due to difficult framework conditions (high costs, shortage of skilled worker, rising interest rate, etc.).

Generally, within the framework of their building portfolio management, housing companies decide about their optimal strategy for each residential property, going from minimum maintenance to complete renovation. The KfW program **"Energy-efficient Refurbishment" (Energieeffizient Sanieren)** is the most significant financial incentive for the housing sector. Under the programme, energy efficient refurbishment projects are supported by loans or grants, through a scaling system rewarding higher theoretical savings: the best standard receives grater funding, but extensive investments are required. Financing is available for the renewal of: windows and exterior doors; ventilation system; heating system; heat distribution and thermal insulation of walls, roof and floor space.

Soft loans at a fixed average interest rate are mostly used, together with a partial debt relief, meaning a grant transferred to the housing companies after completion of the refurbishment according to the energy efficiency reached.

Beyond the support of KfW (covering around the 80%), the remaining 20% is made of **housing companies' own capital.** Regarding the rent increase after renovation, the legislation allows housing companies to increase the yearly rent by an amount equivalent to a maximum of 11% of the investment cost related to the energy modernization, excluding maintenance. However, for the social housing sector, this increase is capped

but there is no limited period, so it is used to finance also the future maintenance and replacement investments.

What are the main policy developments and trends towards renovation?

In 1990 the not-for-profit housing law was abolished, and the privilege of being free from corporate tax came to an end, except than for cooperatives. Because of their non-preferential status, housing providers need to adopt sustainable management strategies. The aim is to combine efficiency (using of social housing as an economic asset) with effectiveness (doing something that can benefit the society). In this process, providers who are members of the GdW are cooperating with different partners and services providers.

Furthermore, the activities of housing organizations are increasingly focusing on rehabilitation measures, measures for **energetic improvement, supported through low-interest loans by the KFW (Kreditanstalt für Wiederaufbau)**. The Federal Government also incorporated the "Social City" programme as a new important task in the Federal Building Code in 2004. The aim of the programme is to combine individual policy areas in a joint strategy to combat the decline of neighbourhoods with a view to building up sustainable structures in deprived areas. As one of the key partners of this programme, housing providers in Germany recognize that urban regeneration is becoming the imperative approach for the future.

Since no particular reference is made to social housing when talking about energy efficiency, general national policies are the main point of reference for GdW. In this regard, **The Energy Saving Ordinance sets energy performance requirements for new buildings and for existing buildings in case of major renovation.** New buildings must not exceed the annual primary energy requirement of a corresponding reference. In exceptional cases there are requirements to retrofit. Where changes are made to existing buildings the affected component must meet minimum energy requirements. Its most recent amendment entered into force in 2014, having as legal basis the **Energy Savings Act (EnEG),** also amended in 2013.

In 2020 the **German Buildings Energy Act (Gebäudeenergiegesetz, GEG)** unified the German Energy Saving Act (EnEG), the German Energy Saving Ordinance (EnEV) and the German Renewable Energies Heat Act (EEWärmeG) setting new mandatory standards for energy-efficient building and refurbishment.

In **2021**, the German Energy Agency (DENA), on behalf of the Federal Ministry of Economic Affairs and Climate Protection, has recently launched the **'Serielle Sanierungslösungen'** project for the large-scale renovation of residential housing stock through digitized design and industrialization of the construction process. Funding programs of more than € 300 million aim at stimulating investments for massive, industrialized interventions through the development of new processes and integrated solutions. Three modules are financed: feasibility studies; research, development and testing of components for pilot projects; design and expansion of production capacity to achieve economies of scale in offsite redevelopments. The aim is to reward innovation and the achievement of high energy performance. The latter is particularly interesting since it's related to the construction of new production facilities or the expansion of existing facilities to adapt to new processes to **roll-out of industrial prefabrication solutions**. This level of direct support addressees the risk incurred by manufacturers when entering the market (DENA, 2021).

In 2023, a 15% percent bonus for serial renovations went into effect as part of the federal subsidy for efficient buildings (**BEG**) operated by the German development bank KfW. The new bonus will make serial refurbishment more attractive for significantly faster implementation since the costs become comparable to those of conventional renovation (International Energy Agency, 2022).

What are the main Energiesprong highlights?

Implementation date	2017 – on going
Market development team	DENA, German Energy Agency
Funding structure	11.6 million shared (Mustbe0, Interreg, 2019-2022) Ministry of Energy in Germany (BMWI)
Achieved results	146 retrofitted houses
Expected results	2570 planned retrofits

April 2017 marked the launch of the Energiesprong initiative into Germany. Based on results in The Netherlands, the Ministry of Energy in Germany (BMWI) has allocated budget to fund a market development team for the coming three years. The high government engagement is demonstrated also in the fact that the MDT is hosted by the **German energy agency DENA**, which is centre of expertise for energy efficiency, renewable energy sources and intelligent energy systems (Energiesprong DE, 2023b).

The first phase of market development is underway. The focus is currently on the development and scaling of solutions for smaller apartment buildings from the 1950s, 1960s and 1970s with a simple shape and a high energy consumption of more than 130 kWh per square meter and year. It's estimated that there are 500,000 of these buildings in Germany a relatively large stock of similar buildings that belong to only a few housing associations. More than 80 housing companies, 16 construction companies and numerous component manufacturers are already involved in bundling demand and developing a modular system for serial renovation solutions.

Initial projects have been implemented for multi-family buildings in **Hameln, Bochum, Herford, Cologne and Mönchengladbach-Lürrip,** achieving energy savings of up to 90 percent. These and other ongoing projects (such as the one in **Mönchengladbach**) have been and are supported by the **EU Interreg NWE Mustbe0 program and/or KFW grants**, through BEG program, according to the energy efficiency standard met (Energiesprong DE, 2023a). So far 68 houses have been retrofitted and more that 500 are about to start: an estimated construction volume of € 300 million in various phases from planning to preparation. Furthermore, more than 100 construction companies are already active, and four new companies for serial refurbishment in Germany have been specifically founded. The first new factories to produce prefabricated elements are in concrete planning, and the first one will start operations shortly (DENA, 2023).

Such numbers, together with the significant 2021 and 2023 funding programs dedicated to serial renovation, show the commitment of German government and construction industry in shifting towards offsite manufacturing. Indeed, the first completed pilot projects demonstrate a high quality of solutions both from a technical and architectural point of view, being, so far, some of the most valuable examples of Energiesprong intervention and regeneration potential. The main characteristics of the first delivered projects are sum up in **Table 5**.

Table 5 *List of completed Energiesprong pilot projects in Germany. Source:* (Energiesprong DE, 2023a)

PHOTO	BUILDING CHARACTERISTICS AND PECULIARITIES	
 	**Location**: Hamelin **Typology:** apartment building 2 floors, 12 residential units 612 m² living space **Provider:** Arsago Real Estate **Main contractor:** Ecoworks **Link to project schedule:** https://www.energiesprong.de/marktentwicklung-aktuell/piloten-und-projekte/steckbrief-pilotprojekt-hameln/	In 2019, the first apartment building in Germany was serially renovated. The pilot has shown that it is technically possible to transfer the serial renovation from single-family houses to multi-family houses and to achieve the NetZero standard in the existing building with prefabricated elements.
	Measures: Facade elements with larch wood cladding (7 meters long, 2.85 meters high and 36 centimeters thick) including insulation made from recycled glass wool, windows and decentralized ventilation elements with heat recovery; insulated roof elements with photovoltaic modules; 20 cm thick basement ceiling insulation; heat pump with two heat storage tanks for heating and hot water; ultra filtration system for water treatment; new radiators in the apartments; smart sensors for optimal control of building technology.	
  	**Location**: Bochum **Typology:** apartment building 4 floors, 32 residential units 2368 m² living space **Provider:** VBW Bauen und Wohnen GmbH **Main contractor:** B&O Bau NRW GmbH **Link to project schedule:** https://www.energiesprong.de/marktentwicklung-aktuell/piloten-und-projekte/mehrfamilienhaus-moerikestrasse-bochum/	The Bochum project is the first in which the serial renovation took place while the building was inhabited. It is also the first in which a decentralized energy module was installed in the apartments, but it resulted in a quite invasive measure. The building material wood met with great approval from the tenants.
	Measures: New facade construction in timber panel construction with 105 large-format prefabricated elements according to the KfW Efficiency House 55 standard; Insulated flat roof, which is fully covered with photovoltaic modules; 16 cm thick basement ceiling insulation with rock wool; Renewal of the heating system with hot water supply and controlled living room ventilation; multifunctional unit for heat supply/hot water preparation and controlled living space ventilation installed in the storage room of each apartment; refurbishment of the stairwells including aluminum doors with thermal insulation glass and conversion of the lighting to LED light; Addition of new 8.40 m2 aluminum projection balconies; Redesign of the outdoor area and barrier-free house entrances.	

<table>
<tr><th>PHOTO</th><th colspan="2">BUILDING CHARACTERISTICS AND PECULIARITIES</th></tr>
<tr><td rowspan="2"> 
  </td><td>Location: Bochum
Typology: apartment building 3 floors, 24 residential units
1164 m² living space
Provider: Vonovia
Main contractor: Fischbach Group
Link to project schedule:
https://www.energiesprong.de/marktentwicklung-aktuell/piloten-und-projekte/pilotprojekt-katharinastrasse-bochum/</td><td>In Bochum Vonovia (the largest housing group in Germany) used a fast, inexpensive insulation method that is particularly sustainable thanks to the use of renewable materials. Another special feature of this pilot project is the brine-water heat pump in combination with geothermal probes.</td></tr>
<tr><td colspan="2">Measures: Prefabricated facade elements in timber frame construction with blow-in insulation; Insulation of the top floor; Photovoltaic on the roof; Brine-water heat pump; geothermal probe; Façade-integrated passive ventilation units near the windows and a decentralized exhaust air system with heat recovery in the attic</td></tr>
<tr><td rowspan="2"> 
  </td><td>Location: Herford
Typology: apartment building 3 floors, 24 residential units
1932 m² living space
Provider: WWS Herford
Main contractor: GAP Solutions GmbH
Link to project schedule:
https://www.energiesprong.de/marktentwicklung-aktuell/piloten-und-projekte/mehrfamilienhaus-ulmenstrasse-herford/</td><td>A special feature of the holistic renovation concept is the innovative solar honeycomb insulation. It ensures that the energy requirement can be reduced by up to 90 percent through the building envelope alone. By adding solar panels, a total of 170 tons of CO2 can be saved per year, moving the building from class H to A.</td></tr>
<tr><td colspan="2">Measures: Panels with glazed solar honeycomb insulation (Cellulosic honeycombs integrated in the glass façade use solar energy to prevent heat loss from occurring in the wall); Insulated roof elements with photovoltaic modules on both sides of the roof and on parts of the facade; All-electric heat and hot water supply using infrared heaters and flow heaters; Window-integrated living space ventilation with heat recovery</td></tr>
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<table>
<tr><th>PHOTO</th><th colspan="2">BUILDING CHARACTERISTICS AND PECULIARITIES</th></tr>
<tr><td rowspan="2"> 
  </td><td>Location: Cologne
Typology: apartment building
4 floors, 16 residential units
992 m² living space
Provider: am Vorgebirgspark eG
Main contractor: Korona-Holzbau
Link to project schedule:
https://www.energiesprong.de/marktentwicklung-aktuell/piloten-und-projekte/mehrfamilienhaus-in-koeln-zollstock/</td><td>The pilot in Cologne is the first Energiesprong project in which an architect's office (Zeller Kölmel Architekten) acted as the creative idea generator, applying circular principles of circular construction (dismountability) and showing that serial renovation can combine energetic modernization with design optimization. Also, the KfW efficiency class 40 plus was achieved for the first time.</td></tr>
<tr><td colspan="2">Measures: Façade elements (wooden frame and small-scale aluminum rhombus finishing laid on site), completely insulated and with pre-assembled windows and doors; Roof insulation using prefabricated elements; Heat pump for central heating, including storage; Hot water via fully electric instantaneous water heater; Integration of sun protection in the façade; Photovoltaic system on the roof for CO2-neutral power generation; new radiators in the apartments (if not yet replaced); New protruding balconies; Façade-integrated ventilation units with heat recovery; Smart sensors and thermostatic valves, smart electricity and heat meters</td></tr>
<tr><td rowspan="2"> 
  </td><td>Location: Mönchengladbach-Lürrip
Typology: apartment building
3 floors, 47 residential units
2750 m² living space
Provider: LEG
Main contractor: Renowate
Link to project schedule:
https://www.energiesprong.de/marktentwicklung-aktuell/piloten-und-projekte/mfh-moenchengladbach-zeppelinstrasse/</td><td>Renowate is a cross-industry joint venture between the housing group LEG and the construction company Rhomberg. It offers complete energy modernization from the initial inventory analysis to turnkey installation. The project marks the beginning of 14 other LEG portfolio properties that the joint venture will realize in 2023.</td></tr>
<tr><td colspan="2">Measures: Prefabricated, elementary wood-frame façade including mineral wool insulation, windows and shutters; Re-roofing and insulation of the roof; the renewal of the plant technology; Insulation of the base areas; Heat pump for central heating, including storage, installed in the attic and fed by public grid (no solar panels); Ventilation units with heat recovery</td></tr>
</table>

Another interesting project, which has not been completed yet, is in **Mönchengladbach** where the housing company LEG has started a **real laboratory for serial renovation based on Energiesprong principles**. Three construction companies were commissioned to develop a scalable refurbishment process for one third of the buildings to modernize them to Net Zero standard. The buildings, built in 1956, have 2 floors each, four to six apartments and, high energy consumption (energy efficiency class H). The goal is to enable climate-neutral living without having to significantly increase rents and promote knowledge exchange between the project participants. Each company will use different technologies and approaches for renovation to test, in real case studies, how innovative concepts can be applied and further improved (Energiesprong DE, 2022).

In the area of non-residential buildings, the Energiesprong market development team is currently preparing the pilot phase for simple office and administrative buildings, while industrialized housing renovation rate is exponentially growing.

4.2.5 Italy

In Italy the official introduction of the term **"Social Housing" (edilizia privata sociale - EPS)** happened for the first time in 2009 with the D.P.C.M. n.191 called "Piano nazionale di edilizia abitativa" (National Housing plan), even though its provision, in the sense it is intended in all other European countries, started in the early twentieth century assuming different names with the evolution of needs and regulations, as it's summarized in the three macro-phases of **Table 6** (Lungarella, 2010; Massaccesi, 2013; Chiara, 2016).

From 1903 to 1971, what is Europe was conceived as social housing, in Italy was called "**folk and affordable houses**" (Case popolari ed economiche). They have been defined for the first time by Luzzatti Law in 1903 and further detailed through the "Consolidated text on folk and affordable houses" (testo unico sulle case popolari ed economiche) in 1908, "Provisions on folk and affordable houses" (Disposizioni sulle case popolari ed economiche) in 1919 and the introduction of PEEPs (Piani di Edilizia Economica e Popolare) in 1962.

From 1971 to 2008 the term **"Public residential housing" (Edilizia Residenziale Pubblica – ERP)** became the official name given in Italy to social housing. It was introduced in 1971 with the "Programs and coordination of Public Residential Building" law (Programmi e coordinamento dell'ERP). It was better characterized in 1978 with the "Regulations for Residential Building" law (Norme per l'edilizia residenziale) and especially in 1992 with the "Regulations for Public Residential Building" (Norme per l'ERP). Under public residential housing, 3 subcategories are mentioned, namely subsidised housing (edilizia sovvenzionata), assisted housing (edilizia agevolata) and agreed housing (edilizia convenzionata), which are better defined in the upcoming sections.

In 2008 a new definition came up under the term of "**Social Residential Housing" (Edilizia residenziale sociale - ERS)** and it refers to "mainly dwellings rented on a permanent basis; also to be considered as social housing are dwellings built or rehabilitated through public and private contribution or with the use of public funding, rented for at least eight years and also sold at affordable price, with the goal of achieving a social mix". Such definition of social house for the purpose of exemption from the obligation to notify State aids can be found it the ministerial decree 22/04/2008. In 2009, instead, the "National Housing plan" (Piano nazionale di edilizia abitativa" was emitted to introduce the concept of "Social Housing" (edilizia privata sociale - EPS) that, together with "Public residential housing" (Edilizia Residenziale Pubblica – ERP) compose the broader "Social Residential Housing" (Edilizia residenziale sociale - ERS). In 2011, with the "Allotment of resources for the National plan of housing" (Riparto delle risorse del Piano nazionale di edilizia abitativa) the above-mentioned structure is finally confirmed. As social housing or EPS, is intended an "Innovative field of development of projects and initiatives aimed at increasing the supply of social housing, through resources and implementation methods proper to the private housing market", financed by the Integrated Fund System (Sistema Integrato dei Fondi - SIF) as explained below.

Table 6 *Historical overview of the Italian social housing system*

1903: Luzzatti Law
1908: Consolidated text on folk and affordable houses
1919: Provisions on folk and affordable houses
1962: Introduction of PEEPs

FOLK AND AFFORDABLE HOUSES

FOLK HOUSES

Houses kept in undivided ownership by the provider and rented to those enrolled to the national social insurance fund with an income lower than 1000 lira per month.

AFFORDABLE HOUSES

Houses built by cooperatives, following low-cost criteria, to be assigned to their members. They can be both sold or rented, even temporarily, at low price.

1971: Programs and coordination of Public Residential Building
1978: Regulations for Residential Building
1992: Regulations for Public Residential Building

PUBLIC RESIDENTIAL HOUSING (ERP)

SUBSIDIZED HOUSING

Rental housing owned by the public sector.

Target: Those with the lowest income.

Provider: Municipalities and public housing agencies.

Finance: Subsidies covering 60%-100% of the overall cost.

ASSISTED HOUSING

Housing provided both for rent and sale.

Target: Those with low to middle income.

Provider: Mainly cooperatives.

Finance: Subsidies covering 20%-60% (rent) or 10%-30% (sale) of the cost.

AGREED HOUSING

Private housing provided both for rent and sale whose price is regulated by an agreement between municipality and provider.

Provider: Private and public entities (building firms and cooperatives).

Finance: Discount on building permission and 99-years lease on land.

2008: Definition of social house for the purpose of exemption from the obligation to notify State aids
2009: National Housing plan
2011: Allotment of resources for the National plan of housing

SOCIAL RESIDENTIAL HOUSING (ERS)

"mainly dwellings rented on a permanent basis; also to be considered as social housing are dwellings built or rehabilitated through public and private contribution or with the use of public funding, rented for at least eight years and also sold at affordable price, with the goal of achieving a social mix"

PUBLIC RESIDENTIAL HOUSING (ERP)

PRIVATE SOCIAL HOUSING (EPS)

"Innovative field of development of projects and initiatives aimed at increasing the supply of social housing, through resources and implementation methods proper to the private housing market". Currently, EPS is mainly implemented through the Integrated Fund System (SIF), introduced by the National Housing Plan.

Who provides social housing?

In Italy, the social housing sector has been characterized by the decentralization of the responsibility for housing provision towards the regions. Before 1998 the regions' budget depended on transfers from the national state. With the reform of 1998 they acquired much more autonomy, and they have to determine their own lines of action, goals, and finance. Within this framework, there are three types of social housing providers: the public sector actors, the cooperatives and the private sector actors.

1. **Public authorities**, like Municipalities and Regions, own and manage public housing stock traditionally targeted to low-income households. In terms of size, over a million dwellings were built in the post-war period, but the public social rental sector got smaller throughout the years because large segments of the stock are continuously being sold off. In 1903 the territorial housing agency IACP (Istituto Autonomo Case Popolari), was created, together with a series of local territorial branches to manage the public stock. It was then transformed into autonomous public agencies with different legal status (nowadays they have various names according to the regional contexts). In 1996 FEDERCASA was born as the transformation of the former ANIACAP (National association of autonomous institutes for popular houses). It associates all the former mentioned local autonomous public agencies and other housing bodies at the provincial, communal and regional level, for a total of 144 entities. It manages around 850.000 dwellings, so more than 90% of the whole social stock.

2. **Housing cooperatives** have been involved in the provision of social housing since 1978. The Alliance of Italian Cooperatives is the main organization representing cooperative consortia. It brings together 4700 cooperatives with 550.000 registered members. Recently, such providers have partially shifted from home ownership to rental offer to better respond to the increasing demand for housing at affordable rent due to the shrinking of public supply. Cooperatives act according to a system of approval at the local level involving their members who benefits of rented or sold apartments.

3. **Private actors** are also entering the social housing scene in the last decades. The 2009 national Housing Plan recognized for the first time a substantial role of private capital in contributing to increase affordable housing supply leading to the entry in the sector of new players, especially dedicated banking foundations. Before 2009, private actors were simply providing agreed-upon rents (locazioni a canone concordato), at a value lower than the market one, in exchange of tax benefits. The most disruptive innovation has been the creation of a new national financing platform SIF (Sistema Integrato dei Fondi) which tap financial resources from a national fund FIA (Fondo Investimenti per l'Abitare), having as main investor Cassa Depositi e Prestiti, which is the national promotional institution that has supported the Italian economy since 1850. The goal is to finance the so called "Social Housing" (edilizia privata sociale - EPS) which is, then, just a very little and recent component of the whole italian social system. The projects financed by FIA are based on public private partnerships. Several projects have been implemented within the SIF since its establishment, creating over 7.500 housing units in multi-family buildings plus an equal number of beds in temporary or student residences. The objective is to build a total of 20.000 dwellings, 8000 of which are planned for 2023.

Who can access social housing?

In general, in Italy, there is a targeted generalist approach because the State leaves the housing management mainly to the market, focusing only to those categories who cannot afford market prices. Indeed, Italian social housing has a mission of general interest in "safeguarding social cohesion, to reduce the housing problems of disadvantaged people and families who are unable to access housing in the open market" ((Pittini and Laino, 2012)(Pittini and Laino, 2012). Regions have the responsibility to define the requirements for access to social hosing, as well as rules for setting rents. As a main distinction, private and cooperative actors mainly address those middle-income households living in a situation of housing distress: they are in need of affordable home ownership or rent. Public social housing, instead, deals with absolute housing emergency of the most vulnerable and low-income population. The eligibility is based on a set of income-

based criteria for registration in waiting lists in all Italian regions. Priority in accessing social housing is given to people in bad living condition, family with several children or to people experiencing enforced cohabitation. There are three main types of publicly supported housing, with slightly different targets and providers:

- **subsidised housing (edilizia sovvenzionata)** is rental housing owned by the public sector, addressing people with the lowest income. It's provided by Municipalities and public housing agencies.
- **assisted housing (edilizia agevolata)** is housing both for rent and sale, addressing people with low to middle income. It's provided mainly by cooperatives.
- **agreed housing (edilizia convenzionata)** is private housing provided both for rent and sale (also building firms) with prices regulated by agreements between the owner and the municipality. It addresses middle income people.

Due to the changes in the socio-demographic structure of the country, social housing providers today must diversify their housing offer, offering housing not only for families, but also for single persons, young people, immigrants, and the elderly. This implies the need to develop special services for tenants.

How is social housing financed?

Broadly speaking, financing is provided by the State. Municipalities together with the Regions co-finance personal aids for the rental sector and allocate land to providers. The central government is responsible for macro programming and co-financing through housing allowances, or funds for urban renewal programmes. Traditionally, as stated above, there are three main types of publicly supported housing in Italy have different financing channels:

- in **subsidised housing (edilizia sovvenzionata**), subsidies cover between 60% and 100% of the cost, and the rents are proportional to the income of the tenants, corresponding on average to ¼ of market rents.
- in **assisted housing (edilizia agevolata**), subsidies are between 20% and 60% of the cost and the rent is limited to the minimum price of the market or the 4.5% of the construction cost. Assisted housing for sale is entitled to 10 - 30% subsidies and the price of the dwelling may not be higher than that of subsidised housing.
- in **agreed housing (edilizia convenzionata**) providers benefit from a discount on the local tax for building permission, and a lease on the land for 99 years.

Most recently, the National Housing Plan, set the basis for new forms of public private partnerships, through the **creation of an integrated real estate fund (SIF) consisting of a national fund (FIA) and a network of local revolving funds (SIF).** The objectives of the Fund are to increase the rental stock managed by the funds at an average rent of approximately 50% of the market rental price and raise the supply of low-cost home ownership. The anticipated target group are people or families not having the requirements to obtain social housing, but unable to meet the market price (Brancaccio, 2011).

Promoters have been mainly foundations (in primis Fondazione Housing Sociale, a private non-profit entity whose mission is to experiment innovative solutions for planning, financing, building and managing social housing initiatives). Cassa Depositi e Prestiti is the reference FIA investor (with 1-billion-euro capital, equal to about 50% of the total endowment) together with the Ministry of Infrastructure and Transport and other private investors. Its manages the fund through its subsidiary CDP Investimenti SGR. The initial commitment, allocated by shareholders was € 1 billion**. Shares are divided among 29 local real estate funds (composing the SIF), which are in turn managed by 9 SGRs.** The latter have also further co-investors, usually local stakeholders (foundations of banking origin, but also regions, provinces, municipalities, housing cooperatives and private developers). Earnings coming form the funds are invested exclusively in local Social Real Estate

projects, rented or sold at affordable prices. This financing modality represents a real revolution in the Italian system since it has the advantages of low risk and high reliability of the expected profitability. However, it's very promising for new private social housing construction but it's not exploitable by current public social housing providers for the renovation of their existing stock. The latter will have to sustain increasing expenditures while income from rents will be reduced. The current trend is to finance social housing provision and refurbishment through sale of the existing stock: to prevent the collapse it's crucial looking for new financing means, both private and public.

How is social housing renovation organized?

Indeed, in contrast with the other European countries analysed, social housing does not perform better than the average residential stock. **Out of the total 2.9 million energy certificates registered in the national registry, more than 75% of them is in class G-F, D covers the 10% and the remaining 15% has a A-B rating**: numbers indicate that the energy efficiency level of dwellings is relatively poor, even though the conditions vary across different providers:

- Generally, the public sector suffers from severe under-funding, hence a low level of new supply and problems with maintenance, management and renovation of the stock (an estimated 10% of the units are vacant since they are not in the condition to be rented).
- The cooperative sector has an higher level of energy retrofit, since stock maintenance is part of their mission and their ownership structure leads to smoother decision making processes with respect to both condominiums and public buildings.
- The new social housing sector built after 2009 and financed by FIA is in a good state, belonging in general to an A/B EPC class and relying on a good share of renewable energy sources (from 35% to 60%).

What are the main policy developments and trends towards renovation?

The European Commission highlights that as of today the social housing system remains inadequate and affected by limited funding, difficult coordination between different government levels and lack of strategic overview. Significant investment is needed to improve the quality and energy efficiency of the stock and increase supply of public housing. This requires stronger support from the central government.

Over the past decade, fiscal incentives for energy retrofit have been significant in terms of amount of public resources used. **Superbonus 110%** has been a strong renovation incentive that was introduced in Italy with Decree Law No. 34 of 2020 (Decreto Rilancio). It planned a deduction equal to 110% of the expenses related to specific energy efficiency (including demolition and reconstruction and installation of photovoltaic panels, with an improvement of at least to EPC classes) and anti-seismic measures (including the implementation of continuous structural monitoring systems). Beneficiaries can include private households, condominiums, cooperatives, public providers, NGOs/associations (Camera dei deputati - Servizio Studi, 2023). To support the program, The National Recovery and Resilience Plan (PNRR) allocated a total of € 13.95 billion to finance the Superbonus. In addition, € 4.56 billion, specifically earmarked for such incentive, have been made available by the Italian PNRR Complementary plan (Piano Complementare) together with a further € 0.32 billion from the EU REACT programme. Overall, € 80 billion of investments have been admitted to fiscal deduction for a total of 400.000 interventions on both condominiums and single-family houses (reaching the 2% of total residential units). Since 2023, the incentive system is still active, but deductions have been reduced to 90%. Furthermore, invoice discounts and credit transfers are no more allowed, so housing owners need to rely on upfront capital (own resources or bank loans) to make the renovation works.

However, even though also public social housing was eligible for Superbonus 110%, overall, the focus has been more on privately owned units but also cooperatives tried to make the most out of it. Public agencies, due to longer procurement processes, were stuck in the frequent regulation changes and postponement. Explicitly for Public Administrations is, instead, available the incentive called **Conto Termico** which finances

up to 65% of expenses incurred for renovation work on the building envelope and technical systems that increase the energy efficiency. In addition, the Ministry of Sustainable Infrastructure and Mobility (Mims) implemented the **National Innovative Program on Housing Quality (PINQuA)**, financed by the National Recovery and Resilience Plan with € 2.8 billion aimed at reducing suburban decay, making public social housing more energy efficient, carrying out urban regeneration interventions and coping with arrears. To each project can be allocated a maximum of € 15 million for interventions which needs to be finished by 2026 (Ministero delle infrastrutture e dei trasporti, 2022).

On the other hand, tight deadlines of current funding programmes (including RRF) keep causing a general rush to implement renovation projects, which is contributing to inflating construction costs and preventing innovation to be developed and delivery, with a predilection to traditional interventions. It's, then, necessary to find a financial and incentive framework stable enough to foster new procurement procedures towards the renovation of significant public social housing volumes.

What are the main Energiesprong highlights?

Implementation date	2021 – on going
Market development team	EDERA, social enterprise for the renovation and decarbonization of the built environment
Funding structure	Fondazione Cariplo The solutions providers involved in the different supply chains.
Achieved results	5 retrofitted houses
Expected results	179 planned retrofits

In **March 2021**, Energiesprong Italy was launched through the founding of **EDERA srl Impresa Sociale**, the innovation centre for decarbonising and retrofitting the built environment. EDERA set up a market development team of six people to implement and adapt the Energiesprong approach to the Italian context. Its intermediation role consists in creating synergies among all supply chain actors (including the social organizations) through a collaborative-competitive process of open and dynamic innovation. In addition, EDERA engage and works with an ecosystem of technical, financial, legal, and social enablers who help solving the emerging barriers spotted through the dialogue with both demand and supply (e.g. market potential, business models, procurement processes, stock clustering, tenant engagement). So far, the market development team has received financial support from Fondazione Cariplo, one of the most influential philanthropic institutions supporting thousands of non-profit organisations and projects in culture, scientific research, environment, and social realms. In addition, also the solution providers who join the network pay an yearly fee (Energiesprong IT, 2023).

In July 2022 the first pilot project was launched. Differently from other countries, it was a private building borough by Woodbeton, a major panel manufacturer and general contractor part of the Italian Energiesprong network. This choice has been forced by boundary conditions: 110% incentives have doped the renovation market, creating a surplus of private renovation demand which made public and social stock less urgent and less appealing (Edera srl Impresa Sociale, 2023).

To date, Energiesprong Italy counts:

- **25 large and small supply companies** within the construction industry who have joined the movement and started to innovate their production processes. Different supply chains have been

created to work on pilot projects, which will be the first Italian examples of deep industrialised retrofits based on different technologies and materials (wood, steel, concrete and hybrid couplings).

- **15 social housing organizations** equally divided between local public agencies members of FEDERCASA and private Cooperatives. In total they own or manage more than 100.000 dwellings. Several meetings and workshops have been organized to sensibilize them and understand what their instances and needs are and how the supply can provide them with proper solutions.
- **4 pilot buildings** spread out across North Italy with a total of almost 200 dwellings to be retrofitted by implementing offsite, integrated components. Since 110% incentives came to an end and the upcoming PNRR line of actions foster public interventions, the private sector became less attractive. For this reason, it has been possible to select a pipeline of buildings coming from public and cooperative housing. Indeed, they have a higher replicability potential and are in urgent need of energy efficiency and energy poverty reduction. The buildings will undergo, not only energy-based retrofits, but also anti-seismic offsite reinforcements, with this being a challenging experiment for the whole Energiesprong European network.

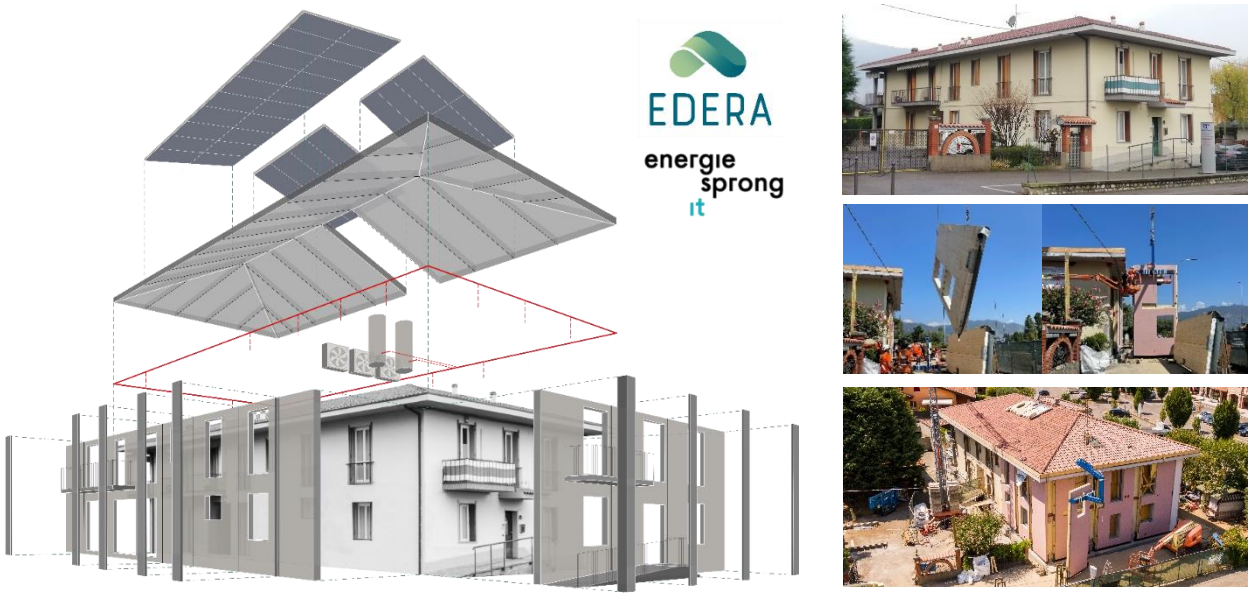

Figure 15 *First Energiesprong project in Italy: 3D scheme with pictures before and during the renovation*

The first Italian Energiesprong intervention was carried out in July 2022, in the municipality of Corte Franca (Lombardy). For the first time in Italy and Southern Europe, the feasibility of NZEB energy efficiency integrated with earthquake-proof upgrading was demonstrated. Adopting offsite technologies, the façade prefabricated panels have been assembled without disturbance to the inhabitants. The retrofit cost (including the suppliers' innovation efforts) stayed within the 110% incentive expenditure ceilings, meaning that it was in line with traditional deep interventions.

The renovated building is a 2-storey house with 5 apartments, chosen because it represents a typical building type in Italian peripheral areas: a horizontal body with punctually arranged balconies, a reinforced concrete frame, brick cladding, and a pitched roof finished with Marseille tiles. The intervention, as schematized in **Figure 15**, was approached by means of new facades and roofing, through the installation of prefabricated wood-frame panels, leaned on a new exterior perimeter foundation and insulated using rock wool. The technical solution adopted is full-electric with heat pump, photovoltaic panels with energy storage and solar thermal system. Such components are located in the attic, and the distribution of heat and domestic hot water takes advantage of vertical cavities cut into the thickness of the new facades, which can be inspected from the outside for maintenance during the life cycle of the building (Edera srl Impresa Sociale, 2023).

The project demonstrates the feasibility of some important Energiesprong requirements:

- **NZEB energy performance level was reached**, with a non-renewable energy consumption index lowered of 80% (from 214 kWh/sqm to 41 kWh/sqm);
- **Anti-seismic performance was improved** through a jump of two classes and change of vulnerability index from 0.09 to 0.60;
- **inconvenience to residents was reduced to the minimum**, thanks to the installation of the façade panels without scaffolding in less than a week and interior works limited to the replacement of radiators with new air terminals for heating/cooling;
- **full-electric building was possible**, using integrated solar thermal system with heat pump for DHW production (57% annual requirement coverage) and 20 kWp photovoltaic system with 46 kWh storage system (103% annual requirement coverage).
- **environmental impact was significantly decreased**, achieving minus 55% $tCO2eq/m^2$ compared to traditional renovations and minus 75% compared to the pre-intervention state[20].

Overall, strengths that characterize Energiesprong in Italy are the attention given to architectural quality (due to the stringent constraints that are peculiar of the Italian heritage), the introduction of anti-seismic improvement. Elements (which require special attention at design and structural level) and the integration of plant systems for summer cooling (given that the temperatures in southern Europe do not allow for insulation alone). These elements not only make the model suitable for the Italian context, but also allow to enrich the catalogue of technological solutions available internationally.
Public organizations are getting more and more aware of the need of alternative and innovative model to efficiently manage their stock due to their limited financial capacity. On the other hand, there are still some barriers to introduce Energiesprong, to the Italian public social housing entities, but the context is evolving and there are opportunities of change in the next few years, starting from policy innovation, volume deals and economies of scale.

[20] The values are calculated over 30 years, considering the life cycle of the building up to 2050, and including the carbon embedded in the retrofit phase. The study was carried out by Politecnico di Milano university.

CONCLUSION

As it emerged by the business model analysis, **Energiesprong** can be considered a valid solution in response to the challenges posed by the European Union, as evidenced by its international diffusion. Indeed, even if it started its implementation in 2010 (before the Paris Agreement was signed), it matches and executes several of the **lead actions listed in the Renovation Wave** (see paragraph 1.1):

- *Making the construction ecosystem fit to deliver sustainable renovation*
  (it's possible thanks to offsite production in a controlled factory environment, which optimizes the integration of activities throughout the whole suppl chain).
- *Placing a smart, integrated, participatory, and neighbourhood-based renovation approach*
  (tenant engagement and involvement is key for the success of the intervention and the preservation of high performances over time)
- *Matching style with sustainability*
  (attention is given to architectural quality and aesthetics so that the new solution is attractive for the building occupants who feel like living in a more valuable house)
- *Using renovation as a lever to address energy poverty and accessibility*
  (the model is based on the assumption to repay the investment with the savings coming from energy bills, which strongly decrease the risk of energy poverty for the tenants)
- *Public buildings and social infrastructure showing the way*
  (having as main target the social housing sector, in many countries means dealing with public buildings and all its peculiarities)
- *Promoting the decarbonisation of heating and cooling*
  (prefabrication allows the integration of technical system within the insulation wall or roof and the installation of efficient heat pumps thanks to the low energy need of the envelope)

Besides all the benefits brought the use of off construction for renovation (see paragraph 3.2), another Energiesprong strength, which emerged from the country overviews, is the fact of being based on few key and characterizing pillars while, at the same time, being **flexible enough to be adapted to different country contexts.** Indeed, social housing is only the starting point but the model has already been tested on private buildings (NL, IT), schools (NL, FR), student accommodations (FR), offices (NL, DE) and administrative buildings (DE).

Furthermore, Energiesprong kick off in France, United Kingdom and Germany, is a clear example of how **EU funds** (such as H2020 Transition Zero and Interreg E = 0 / Must Be Zero projects) **can be exploited** to introduce such approach in new markets. Currently, instead, the EU projects in which Energiesprong is involved (LIFE Giga Regio Factory / Energy Poverty Zero) are more oriented in studying scalability and sustainable replicability of the model to get to renovate more buildings and faster.

Indeed, even if Energiesprong is at front-edge of industrial deep renovation, with 7.000 residential units fully retrofitted, **its pace alone is far from reaching EU targets**. Firstly, to meet the Renovation Wave goal of decreasing greenhouse gas emission by 60% with respect to 2015 levels, housing must reduce building releases of around 20 Mt Co_2e per year from 2020 to 2030 (see paragraph 2.1). Since according to the French Observatory, one full retrofit enables to save around 1t Co2e per year, 2.000.000 deep renovations (reaching Energiesprong performances) are hypothetically needed the first year to meet the goal once for all. Indeed, thanks to the performance guarantee, such savings are linked to the operational life cycle, and they are maintained over time. However, the number of interventions already realized in 2021 and 2022 is much lower, implying that the retrofit rate must increase exponentially to be in line with the yearly average.

Moreover, moving specifically to analysed countries' social housing, if the **recast EPBD** come into force (see paragraph 1.2), all residential buildings need to reach at least Class D by 2033. In The Netherlands, France, United Kingdom, Germany, and Italy, which have -except the latter- a well performing social stock, are required to renovate around 2.800.000 in 10 years: the 20.000 interventions planned so far across Countries are clearly not sufficient!

To become effectively revolutionary, joint efforts, from the supply and demand side are needed to quickly cluster buildings according to typology, needs and constraints. Thus, it is possible to catalogue industrial solutions and make them available for different stock archetypes. Parallelly, the variety of national financial and regulatory frameworks should take a common path to clearly state the main retrofit drivers and benefits. For all involved stakeholders. Indeed, despite all the long-term expenses of inadequate houses and the benefits that energy savings can bring, social housing renovation is not always a priority.

The latter reflection opens the way to the limitations of the present thesis and the **suggested further research**. The work, being an exhaustive overview of Energiesprong industrialized deep renovation, forms the basis for **country-specific case studies**, since no detailed analysis have been presented.

Case studies can follow two main paths:

- The former remains more **qualitative**, and it focuses on the **current technical, financial, social and legal barriers** faced in the realized projects, which in the current work have only been mentioned in a scattered way. The empirical understanding of recurrent problems and challenges is crucial to activate the right ecosystem able to overcome them and open the way to massification.
- The latter is more **quantitative** since, beside al boundary conditions, the **economic feasibility of each project** must be guaranteed. for it to be replicable even without EU funds. Targeted case studies should, then start to quantify all the benefits linked to offsite renovation process that in the thesis have been just listed qualitative. They need to be first evaluated on country-specific pilot projects to, then, be generalized and valorised in quantitative estimations. The collection of multiple values enables the creation of a computational model for cash flow analysis and convenience evaluations of offsite deep retrofits.

From a broader point of view, enlarging the Energiesprong perspective which is clearly based on one-step whole-house interventions, two further considerations can be made:

- **Deep staged renovation**, as stated in the ongoing EPBD revision, seems to be a valid cost-effective alternative if proper Building Renovation Passport are in place and the different interventions are partially planned and designed in advance. Indeed, each building and project remains unique, and decisions about how to decarbonize it most effectively need to be made on a case-by-case basis. Staged renovation can be needed when high up-front capital is not available while smaller and spread liquidity can be obtained over time, without incurring in high interests' costs. Business cases with different scenarios are a fair option to compare different possibilities.
- Deep retrofits fit well also in all those reasonings related to **energy communities** which are associations that produce and share renewable energy, generating and managing cost-effective green energy autonomously. They can be composed by local citizens, condominiums, schools, public administrations, enterprises, and they generally reach the size of a district, though the regulatory and infrastructural framework is often not ready yet. Energy communities will be the future response to zero-emissions targets especially for those residential high-rise buildings that, despite minimizing energy needs, can't cover them with own renewable sources. Start to reason to Energiesprong as part of an energy community offers great opportunities concerning reduction of barriers, economies of scale, supply chains collaborations and urban regeneration impacts.

APPENDIX A – Energy flows and Primary Energy factors for nZEB buildings

The aim of appendix A is to provide some definitions needed to understand the types of energy flows which are monitored in statistical analysis and mentioned in legislative documents. A simplified version of the overall energy process is shown in **Figure** and described below.

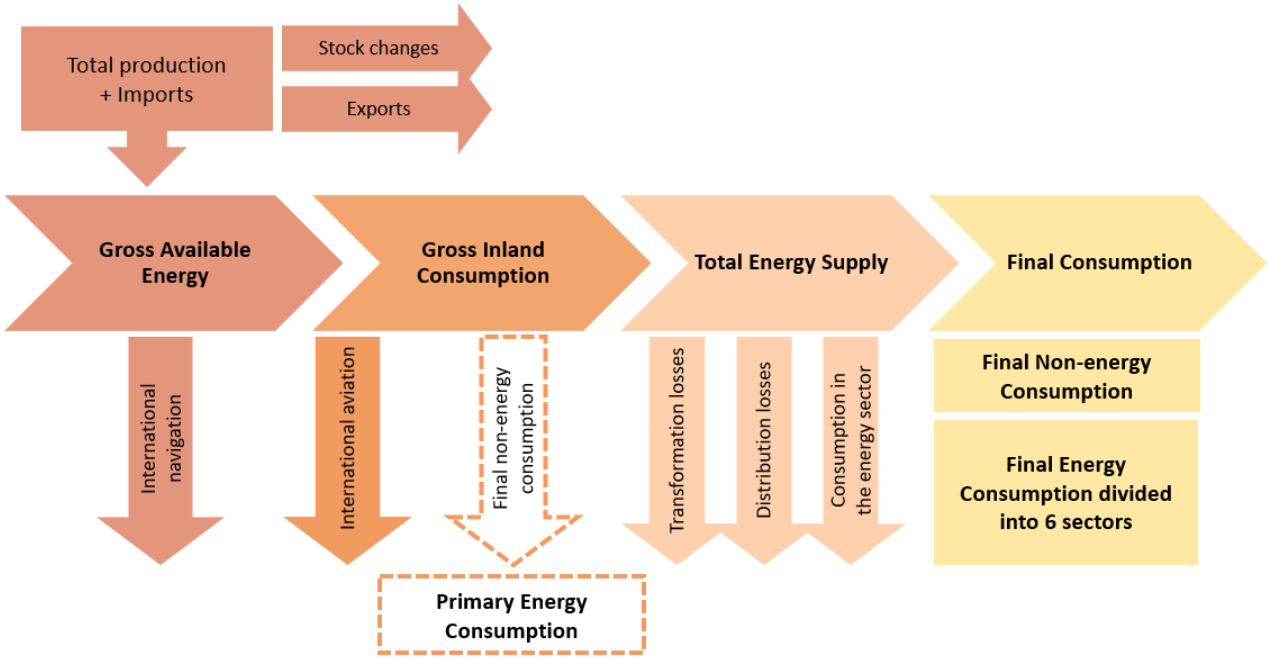

Figure A.1 *Energy flows from production to consumption. Adapted from:* (European Commission DG Energy, 2021).

- **Gross Available Energy** represents the energy quantity needed to satisfy the whole demand of the entities operating under the authorities of the analysed geographical area. It's composed by the total production and the net imports (imports – exports) considering the stock changes.
- **Gross Inland Consumption** is the gross available energy excluding the energy consumed by the international maritime bunkers. It is calculated to ensure transition from the old Eurostat energy balance to the new one.
- **Total Energy Supply** represents the quantity of energy necessary to satisfy the inland consumption of the analysed geographical area. It is the gross inland consumption without the international aviation demanded energy.
- **Final Consumption** is the energy available to the final consumer and it's divided in **final energy consumption** when used for energy purposes in all the sectors (industry, transport, households/residential, commercial and public services, agriculture forestry and fishing, others) and **final non-energy consumption** when used for its chemical properties and not as fuel (such as natural gas in fertilizers). It differs from the total energy supply since consumptions within the energy sector and transformation/distribution losses have been removed.
- **Primary Energy Consumption** corresponds to the Gross Inland Consumption minus the energy included in the final non-energy consumption. It's the energy that has not undergone any conversion in the transformation process.

Primary (PEC) and Final (FEC) Energy Consumption are the only flows analysed for the purposes of this thesis since they are the main target of energy efficiency indicators, goals, and regulations in all sectors and especially in the building construction industry.

To be able to properly shift from final to primary energy values within a specific sector but also for a specific building, **Primary Energy factors (PEFs)** are used. In fact, the final energy available to end-users is provided

by energy carriers, fuels which occupy intermediate steps in the supply chain with the role of energy transmitters. They can come from on-site primary renewable energy sources (photovoltaic and solar thermal panels, HP heat pumps) or from the outside through the electricity, heat and gas grids, whose carriers can be generated by both primary renewable (biofuels, solar, wind, geothermal and hydro power, renewable waste heat) and non-renewable (fossil fuels, peat products, derived heat and non-renewable waste heat) sources. Therefore, primary energy factors are the ratio of a given type of primary energy to the final energy amount delivered through different energy carriers (Gabaldón Moreno, Alpagut and Hernández Iñarra, 2020). They have a different value depending on the type of primary source involved, since they take into accounts its specific transformation and distribution losses. PEFs are divided into:

- **PEF_{nren}** which proves how much primary energy from non-renewable sources is used to generate a unit of final energy
- **PEF_{nen}** which proves how much primary energy from renewable sources is used to generate a unit of final energy
- **TPEF** which is the sum of PEF_{nren} and PEF_{ren} and it represents the total primary energy needed to produce a unit of final energy.

These factors are mentioned in both the EU Energy Efficiency Directive (EED) and in the EU Energy Performance of Buildings Directive (EPBD) which set targets and recommendations to reduce the primary energy demand for buildings and increase the overall energy efficiency. The choice of PEF values is always left to each Member States, due to the specificity of a Country's energy mix and power plants performances. As it emerges by several studies, the problem lies in the **lack of a common framework** to calculate them even if reference values are provided by the **standard EN ISO 52000-1** and reported in **Table A.1** (Gabaldón Moreno, Alpagut and Hernández Iñarra, 2020). Furthermore, changes in the energy market also require regular recalculation of PEFs to obtain up-to-date values. If the use of PEFs to calculate the Energy Performance of buildings is incorrect this may misguide market and policy makers, due to unprecise estimated energy savings. Indeed, looking at the numbers in Table A.1, the ratio of the PEF between different energy carriers is also a key element in defining the relative performance of technical building systems: the higher the PEF_{nren}, the lower the convenience to adopt solutions powered by such carrier (Zirngilb, 2020). **Variations consequently impact international benchmark and the definition of nearly zero energy buildings** since the nZEB calculation is linked to buildings energy needs, which are covered by certain systems consuming a given amount of final energy that is converted into primary energy through PEFs. Energy balance is, then, derived as the difference between primary energy demand and generated energy over a one-year period. For instance, depending on PEFs value, the nZEB level will be reached more or less easily by certain technologies. In conclusion, PEFs should reflect national energy contexts but greater transparency in the methodology of calculus is needed to have a better understanding of the possible reasons for differences (Hitchin, 2019).

Table A.1 *Primary Energy factors (PEFs) reported in the standard EN ISO 52000-1*

ENERGY CARRIER	PEF_{nren}	PEF_{ren}	TPEF
Solar (PV, PVT, FPC..)	0	1	1
Environment (geo, aero, hydro – thermal)	0	1	1
Biofuels solid	0,2	1	1,2
Biofuels liquid	0,5	1	1,5
Biofuels gaseous	0,4	1	1,4
Waste Heat	0	1	1
Electricity grid (imported and exported)	2,3	0,2	2,5
Fossil fuels solid	1,1	0	1,1
Fossil fuels liquid	1,1	0	1,1
Fossil fuels gaseous	1,1	0	1,1
District heating/cooling	1,3	0	1,3

APPENDIX B – List of European project addressing deep renovation

Table B.1 *H2020, Horizon Europe, Interreg and LIFE projects tackling with industrialized and integrated technologies*

ACRONYM	EXPLANATION TITLE	PROGRAM	START DATE	LINK
4RinEU	Robust and Reliable technology concepts and business models for triggering deep Renovation of Residential buildings in EU	H2020	01/10/2016	https://cordis.europa.eu/project/id/723829
ABRACADABRA	Assistant Buildings' addition to Retrofit, Adopt, Cure And Develop the Actual Buildings up to zeRo energy, Activating a market for deep renovation	H2020	01/03/2016	https://cordis.europa.eu/project/id/696126
AEGIR	DigitAl and physical incrEmental renovation packaGes/systems enhancing envIronmental and energetic behaviour and use of Resources	HEUROPE	01/10/2022	https://cordis.europa.eu/project/id/101079961
BERTIM	Building energy renovation through timber prefabricated modules	H2020	01/06/2015	https://cordis.europa.eu/project/id/636984
Be-Smart	BE-Smart: Innovative Building Envelope for Sustainable, Modular, Aesthetic, Reliable and efficient construction	H2020	01/10/2018	https://cordis.europa.eu/project/id/818009
BRESAER	Breakthrough solutions for adaptable envelopes for building refurbishment	H2020	01/02/2015	https://cordis.europa.eu/project/id/637186
DRIVE 0	Driving decarbonization of the EU building stock by enhancing a consumer centred and locally based circular renovation process	H2020	01/10/2019	https://cordis.europa.eu/project/id/841850
E2VENT	Energy Efficient Ventilated Façades for Optimal Adaptability and Heat Exchange enabling low energy architectural concepts for the refurbishment of existing buildings	H2020	01/01/2015	https://cordis.europa.eu/project/id/637261
EENSULATE	Development of innovative lightweight and highly insulating energy efficient components and associated enabling materials for cost-effective retrofitting and new construction of curtain wall facades	H2020	01/08/2016	https://cordis.europa.eu/project/id/723868
ENERPAT	Co-creation of Energetically efficient territorial solutions of Patrimonial Residential habitat Ecorenovation in SUDOE historical centres	INTERREG	2016-07-01	https://www.enerpatsudoe.fr/
ENSNARE	ENvelope meSh aNd digitAl framework for building REnovation	H2020	01/01/2021	https://cordis.europa.eu/project/id/958445
Envision	ENergy harVesting by Invisible Solar IntegratiON in building skins	H2020	01/10/2017	https://cordis.europa.eu/project/id/767180
e-SAFE	Energy and Seismic AFfordable rEnovation solutions	H2020	01/10/2020	https://cordis.europa.eu/project/id/893135
EXCESS	FleXible user-CEntric Energy poSitive houseS	H2020	01/09/2019	https://cordis.europa.eu/project/id/870157

FORTESIE	CBDC powered Smart PerFORrmance contracTs for Efficiency, Sustainable, Inclusive, Energy use	HEUROPE	01/09/2022	https://cordis.europa.eu/project/id/101080029
GREEN INSTRUCT	Green Integrated Structural Elements for Retrofitting and New Construction of Buildings	H2020	01/10/2016	https://cordis.europa.eu/project/id/723825
H4.0E	Housing 4.0 Energy	INTERREG	2018-05-31	http://www.nweurope.eu/
HEART	Holistic Energy and Architectural Retrofit Toolkit	H2020	01/10/2017	https://cordis.europa.eu/project/id/768921
Heat4Cool	Smart building retrofitting complemented by solar assisted heat pumps integrated within a self-correcting intelligent building energy management system.	H2020	03/10/2016	https://cordis.europa.eu/project/id/723925
IMPRESS	New Easy to Install and Manufacture PRE-Fabricated Modules Supported by a BIM based Integrated Design ProceSS	H2020	01/06/2015	https://cordis.europa.eu/project/id/636717
InCUBE	An INClUsive toolBox for accElerating and smartening deep renovation	HEUROPE	01/07/2022	https://cordis.europa.eu/project/id/101069610
INFINITE	Industrialised durable building envelope retrofitting by all-in-one interconnected technology solutions	H2020	01/11/2020	https://cordis.europa.eu/project/id/958397
InnoWEE	Innovative pre-fabricated components including different waste construction materials reducing building energy and minimising environmental impacts	H2020	01/10/2016	https://cordis.europa.eu/project/id/723916
INPERSO	INdustrialised and PErsonalised Renovation for Sustainable sOcieties	HEUROPE	01/07/2022	https://cordis.europa.eu/project/id/101069820
INSUPanel	Building the green way: wide take-up of a versatile, proven, energy and cost efficient insulation technology	H2020	01/08/2017	https://cordis.europa.eu/project/id/768079
LIFE BuildUPspeed	Creating a Market Activation Platform to speed up the renovation of EU buildings	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101075843
LIFE COHEAT2	Bolstering energy transition renovation in south Denmark	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101076568
LIFE Conipher	CONcrete Insulation PHotovoltaic Envelop for deep Renovation	LIFE14	01/09/2015	https://webgate.ec.europa.eu/life/publicWebsite/project/details/4209
LIFE IP BUILDEST	Pursuing estonian national climate ambition through smart and resilient renovation	LIFE20	01/11/2021	https://webgate.ec.europa.eu/life/publicWebsite/project/details/5815
Low Tech	Alpine Building	INTERREG	2016-10-31	http://www.interreg.net/
Low-Tech-Gebäude	Concepts for energy-efficient, climate-friendly “LOW-TECH” buildings in the Lake Constance area	INTERREG	2015-12-01	http://www.interreg.org/
MORE-CONNECT	Development and advanced prefabrication of innovative, multifunctional building envelope elements for MOdular REtrofitting and CONNECTions	H2020	01/12/2014	https://cordis.europa.eu/project/id/633477

nZECom	Sustainable and almost zero-emission communities and the role of public buildings - nZECom	INTERREG	2019-12-01	http://interreg-med.eu/en
oPEN Lab	Open innovation living labs for Positive Energy Neighbourhoods	H2020	01/10/2021	https://cordis.europa.eu/project/id/101037080
outPHit	Promoting energiesprong renovations and one-stop-shop retrofit concepts in highly efficient nzebs in enerphit standard, to make renovation more reliable, faster and cost-effective	H2020	01/09/2020	https://cordis.europa.eu/project/id/957175
P2Endure	Plug-and-Play product and process innovation for Energy-efficient building deep renovation	H2020	01/09/2016	https://cordis.europa.eu/project/id/723391
PLUG-N-HARVEST	PLUG-N-play passive and active multi-modal energy HARVESTing systems, circular economy by design, with high replicability for Self-sufficient Districts Near-Zero Buildings	H2020	01/09/2017	https://cordis.europa.eu/project/id/768735
PLURAL	Plug-and-use renovation with adaptable lightweight systems	H2020	01/10/2020	https://cordis.europa.eu/project/id/958218
POWERSKIN PLUS	Highly advanced modular integration of insulation, energising and storage systems for non-residential buildings	H2020	01/10/2019	https://cordis.europa.eu/project/id/869898
Pro-GET-OnE	Proactive synergy of inteGrated Efficient Technologies on buildings' Envelopes	H2020	01/05/2017	https://cordis.europa.eu/project/id/723747
RE4	REuse and REcycling of CDW materials and structures in energy efficient pREfabricated elements for building REfurbishment and construction	H2020	01/09/2016	https://cordis.europa.eu/project/id/723583
ReCO2ST	Residential Retrofit assessment platform and demonstrations for near zero energy and CO2 emissions with optimum cost, health, comfort and environmental quality.	H2020	01/01/2018	https://cordis.europa.eu/project/id/768576
REHOUSE	Renovation packagEs for HOlistic improvement of EU's bUildingS Efficiency, maximizing RES generation and cost-effectiveness	HEUROPE	01/10/2022	https://cordis.europa.eu/project/id/101079951
re-MODULEES	the Retrofitting Market Activation Platform based on the generation of standard modules for energy efficiency and clean energy solutions	H2020	01/11/2020	https://cordis.europa.eu/project/id/955529
RenoZEB	Accelerating Energy renovation solution for Zero Energy buildings and Neighbourhoods	H2020	01/10/2017	https://cordis.europa.eu/project/id/768718
RE-SKIN	Renewable and Environmental-Sustainable Kit for building INtegration	HEUROPE	01/01/2023	https://cordis.europa.eu/project/id/101079957
REZBUILD	REfurbishment decision making platform through advanced technologies for near Zero energy BUILDing renovation	H2020	01/10/2017	https://cordis.europa.eu/project/id/768623
RINNO	An augmented intelligence-enabled stimulating framework for deep energy renovation delivering occupant-centered innovations	H2020	01/06/2020	https://cordis.europa.eu/project/id/892071

SaveSmart	Improvement of housing energy performance level of public buildings through introducing innovative technologies and solutions in Estonia and Pskov region	INTERREG	2019-06-01	http://www.estoniarussia.eu/
SRE	Smart roof edge technology	H2020	01/12/2017	https://cordis.europa.eu/project/id/791535
StepUP	Solutions and Technologies for deep Energy renovation Processes UPtake	H2020	01/08/2019	https://cordis.europa.eu/project/id/847053
Surefit	Sustainable solutions for affordable retrofit of domestic buildings	H2020	01/09/2020	https://cordis.europa.eu/project/id/894511
TRAC 4 SERIAL	TRAnsnational Cooperation for Serial Energy Refurbishment in BSR	INTERREG	2020-10-01	http://www.interreg-baltic.eu/home.html
VEEP	Cost-Effective Recycling of CDW in High Added Value Energy Efficient Prefabricated Concrete Components for Massive Retrofitting of our Built Environment	H2020	01/10/2016	https://cordis.europa.eu/project/id/723582

Table B.2 *H2020, Horizon Europe, Interreg and LIFE projects addressing policy, government support, supply chain cooperation and stakeholders' involvement*

ACRONYM	EXPLANATION TITLE	PROGRAM	START DATE	LINK
0260_RENERPATH_2_6_E	Methodology of energy rehabilitation of heritage buildings 2	INTERREG	2015-07-01	http://www.poctep.es/
Accelerate SUNShINE	Save your bUildiNg by SavINg Energy. Begin to move more quickly	H2020	01/04/2017	https://cordis.europa.eu/project/id/754080
ACE-Retrofitting	Accelerating Condominium Energy Retrofitting	INTERREG	2016-09-15	http://www.nweurope.eu/
ALDREN	ALliance for Deep RENovation in buildings (ALDREN) Implementing the European Common Voluntary Certification Scheme, as back-bone along the whole deep renovation process.	H2020	01/11/2017	https://cordis.europa.eu/project/id/754159
BENEFIT	Building ENergy Efficiency ImprovemenT: Demonstration for public buildings	INTERREG	2018-10-20	http://www.ipa-cbc-programme.eu
BUILD UPON	A multi-stakeholder Regional Action Network as a living structural base to effectively help define and implement deep energy efficient building renovation at local, national and European level.	H2020	01/03/2015	https://cordis.europa.eu/project/id/649727
BUILD UPON2	Supporting public sector's capacity and leadership in decarbonising Europe's building stock, through the development of a multi-level renovation impact framework	H2020	01/06/2019	https://cordis.europa.eu/project/id/840926
BUILD2LC	Boosting low carbon innovative building rehabilitation in european regions	INTERREG	2016-04-01	http://www.interregeurope.eu/
CITYnvest	Increasing Capacities in Cities for Innovative Financing in Energy Efficiency	H2020	01/02/2015	https://cordis.europa.eu/project/id/649730
COLEOPTER	Local consultation for the territorial policies consultations on rural energy	INTERREG	2019-10-01	https://www.interreg-sudoe.eu/

crossCert	Cross Assessment of Energy Certificates in Europe	H2020	01/09/2021	https://cordis.europa.eu/project/id/101033778
E=0	Creating a mass market for net zero energy retrofits in NWE	INTERREG	2016-05-25	http://www.nweurope.eu/
eCentral	Energy Efficient Public Buildings in Central Europe	INTERREG	2017-09-01	https://programme2014-20.interreg-central.eu/
EEBAK	Energy efficiency of buildings in Arctic municipalities	INTERREG	2017-01-01	http://www.interregnord.com/
EERAdata	Data-driven decision-support to increase energy efficiency through renovation in European building stock.	H2020	01/07/2019	https://cordis.europa.eu/project/id/847101
Efficient Buildings	Efficient Buildings	INTERREG	2019-11-01	http://interreg-med.eu/en
EmBuild	Empower public authorities to establish a long-term strategy for mobilizing investment in the energy efficient renovation of the building stock	H2020	01/03/2016	https://cordis.europa.eu/project/id/695169
Energy Pathfinder	Approaching Near Zero Energy in Historic Buildings	INTERREG	2019-06-01	http://www.interreg-npa.eu/ (not verified)
ENLEB	ENLEB	INTERREG	2017-06-01	http://www.kampc.be/enleb
EPC RECAST	Energy Performance Certificate Recast	H2020	01/09/2020	https://cordis.europa.eu/project/id/893118
ExcEED	ExcEED – European Energy Efficient buildingdistrict Database: from data to information to knowledge	H2020	01/09/2016	https://cordis.europa.eu/project/id/723858
FAMARB	Facility Management of Residential Buildings in Barents Region	INTERREG	2018-12-01	https://kolarctic.info/
FEASIBLE	Fostering Sustainable Living cities	H2020	13/05/2019	https://cordis.europa.eu/project/id/847118
Fit-to-nZEB	Innovative training schemes for retrofitting to nZEB-levels	H2020	15/06/2017	https://cordis.europa.eu/project/id/754059
GOAL nZEBs	Greece cOllaborates with Albania for nZEBs - Goal nZEBs	INTERREG	2019-12-01	http://interreg-med.eu/en
Green Building A-Z	Green Building A-Z	INTERREG	2016-09-01	http://www.interreg-oks.eu/
GREEN Home	German Roundtables on Energy Efficiency in Homeowner Associations	H2020	01/10/2021	https://cordis.europa.eu/project/id/101033878
GReENEFF	Cross-border network to support innovative sustainable development and energy sobriety projects in the Greater Region	INTERREG	2016-04-01	http://www.interreg-gr.eu
GreenSan	Cross-border energy-efficient and sustainable renovation that protects resources	INTERREG	2016-01-01	http://www.interreg.org/
HAPPEN	Holistic AProach and Platform for the deep renovation of the med residential built ENvironment	H2020	01/04/2018	https://cordis.europa.eu/project/id/785072
HAPPI	Housing Association's Energy Efficiency Process Planning and Investments	H2020	01/03/2018	https://cordis.europa.eu/project/id/785147
iBROAD	Individual Building (Renovation) Roadmaps	H2020	01/06/2017	https://cordis.europa.eu/project/id/754045
iBRoad2EPC	Integrating Building Renovation Passports into Energy Performance Certification schemes for a decarbonised building stock	H2020	01/09/2021	https://cordis.europa.eu/project/id/101033781

I-HEROS	Integrated Home Energy RenOvation Service	H2020	01/09/2020	https://cordis.europa.eu/project/id/890598
IMPULSE	Integrated Management Support for Energy efficiency in Mediterranean PUblic buiLdings	INTERREG	2016-11-01	http://interreg-med.eu/en
IMPULSE PLUS	Reaching new territories in the use of Integrated Management Support tools for Energy efficiency in Mediterranean PUblic buiLdings	INTERREG	2021-03-01	http://interreg-med.eu/en
IWG5-CSA	Expert support to Implementation Working Group 5 of the SET Plan - Energy Efficiency in Buildings	HEUROPE	01/09/2022	https://cordis.europa.eu/project/id/101075700
LIFE BUS2FRANCE	Building skills for energy-efficient renovation in France	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101077273
LIFE BUS-NL	Building skills to speed up the renovation wave	LIFE CET	01/10/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101077358
LIFE CONCERTO RENOV	Supporting energy transition renovations through improved scenarios and streamlined communication	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101077038
LIFE Construye 2030	Building skills in the Spanish construction sector	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101077607
LIFE EconomisE	Value for money: unlocking the investment potential for resilient low-carbon Finnish building stock	LIFE16	15/06/2017	https://webgate.ec.europa.eu/life/publicWebsite/project/details/4669
LIFE EP-0	Reducing the cost of energy transition renovations in social housing areas	LIFE CET	01/11/2022	N.A.
LIFE LEAP	Promoting Local Energy Agencies in peripheral regions	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101077163
LIFE GigaRegioFactory	Developing tools to meet the growing demand for net zero energy renovation	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101077258
LIFE IP BE REEL!	Belgium Renovates for Energy Efficient Living	LIFE16	01/01/2018	https://webgate.ec.europa.eu/life/publicWebsite/project/details/4830
LIFE RENOVERTY	Home renovations to address rural energy poverty	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101077272
LIFE REVERTER	Improving energy efficiency to reduce energy poverty	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101076277
MEnS	Meeting of Energy Professional Skills	H2020	01/03/2015	https://cordis.europa.eu/project/id/649773
MODER	Mobilization of innovative design tools for refurbishing of buildings at district level	H2020	01/09/2015	https://cordis.europa.eu/project/id/680447
MUSTBE0	MUlti STorey Building E=0 refurbishment	INTERREG	2019-01-10	http://www.nweurope.eu/
NEWCOM	New competence for building professionals and blue collar workers – certified qualification schemes to	H2020	01/09/2017	https://cordis.europa.eu/project/id/754148

	upgrade the qualification for building nZEBs			
NewTREND	New integrated methodology and Tools for Retrofit design towards a next generation of ENergy efficient and sustainable buildings and Districts	H2020	01/09/2015	https://cordis.europa.eu/project/id/680474
nZEB Ready	Enhancing Market Readiness for nZEB Implementation	H2020	01/09/2021	https://cordis.europa.eu/project/id/101033733
PENNY	Psychological, social and financial barriers to energy efficiency	H2020	01/09/2016	https://cordis.europa.eu/project/id/723791
PROBONO	The Integrator-centric approach for realising innovative energy efficient buildings in connected sustainable green neighbourhoods	H2020	01/01/2022	https://cordis.europa.eu/project/id/101037075
PROF-TRAC	PROFessional multi-disciplinary TRAining and Continuing development in skills for NZEB principles	H2020	01/03/2015	https://cordis.europa.eu/project/id/649473
QualDeEPC	High-quality Energy Performance Assessment and Certification in Europe Accelerating Deep Energy Renovation (QualDeEPC)	H2020	01/09/2019	https://cordis.europa.eu/project/id/847100
REBUS	Renovation for Energy efficient BUildingS	INTERREG	2016-04-01	http://www.interregeurope.eu/
REFURB	REgional process innovations FOR Building renovation packages opening markets to zero energy renovations	H2020	01/04/2015	https://cordis.europa.eu/project/id/649865
REGENERATE	Stimulating eco-sustainable home renovation to maximize social, environmental and economic impact on the Balearic Islands	H2020	01/06/2021	https://cordis.europa.eu/project/id/101025164
RENOVALT	Rénovation-Energie-Alternance	INTERREG	2018-01-04	https://renovalt.eu/
Renovation Center	A Nordic Center for Energy Efficient Renovations	INTERREG	2015-04-01	http://www.nordicrenovationcenter.fi
SEEtheSkills	Sustainable EnErgy Skills in construction: Visible, Validated, Valuable	H2020	01/06/2021	https://cordis.europa.eu/project/id/101033743
SHERPA	SHared knowledge for Energy renovation in buildings by Public Administrations	INTERREG	2016-11-01	http://interreg-med.eu/en
Shine	Sustainable houses in an inclusive Neighbourhood	INTERREG	2016-09-01	http://www.interreg2seas.eu/
SmartLivingEPC	Advanced Energy Performance Assessment towards Smart Living in Building and District Level	HEUROPE	01/07/2022	https://cordis.europa.eu/project/id/101069639
SOLE (ex HELIOS)	High Energy efficiency for the pubLIc stOck buildingS in Mediterranean	INTERREG	2020-07-10	http://www.enicbcmed.eu/projects/sole
Stronghouse	Sustainable housing for strong communities	INTERREG	2020-01-01	https://northsearegion.eu/stronghouse
SURE2050	SUstainable Real Estate 2050	H2020	01/05/2019	https://cordis.europa.eu/project/id/844902
TRANSITION ZERO	Make Net Zero Energy refurbishments for houses a mass market reality	H2020	01/03/2016	https://cordis.europa.eu/project/id/696186
TripleA-reno	Attractive, Acceptable and Affordable deep Renovation by a consumers orientated and performance evidence based approach	H2020	01/05/2018	https://cordis.europa.eu/project/id/784972

U-CERT	Towards a new generation of user-centred Energy Performance Assessment and Certification; facilitated and empowered by the EPB Center	H2020	01/09/2019	https://cordis.europa.eu/project/id/839937
ZEROCO2	Promotion of near zero CO2 emission buildings due to energy use	INTERREG	2016-04-01	http://www.interregeurope.eu/

Table B.3 *H2020, Horizon Europe, Interreg and LIFE projects highlights digital related projects related to renovation*

ACRONYM	EXPLANATION TITLE	PROGRAM	START DATE	LINK
AGREE	Aggregation and improved Governance for untapping Residential Energy Efficiency potential in the Basque Country	H2020	01/09/2019	https://cordis.europa.eu/project/id/847068
BIGG	Building Information aGGregation, harmonization and analytics platform	H2020	01/12/2020	https://cordis.europa.eu/project/id/957047
BIM4EEB	BIM based fast toolkit for Efficient rEnovation in Buildings	H2020	01/01/2019	https://cordis.europa.eu/project/id/820660
BIM4REN	Building Information Modelling based tools & technologies for fast and efficient RENovation of residential buildings	H2020	01/10/2018	https://cordis.europa.eu/project/id/820773
BIMERR	BIM-based holistic tools for Energy-driven Renovation of existing Residences	H2020	01/01/2019	https://cordis.europa.eu/project/id/820621
BIM-SPEED	Harmonised Building Information Speedway for Energy-Efficient Renovation	H2020	01/11/2018	https://cordis.europa.eu/project/id/820553
CHRONICLE	Building Performance Digitalisation and Dynamic Logbooks for Future Value-Driven Services	HEUROPE	01/07/2022	https://cordis.europa.eu/project/id/101069722
CORSAIR	Increasing the quality mindset of COnstruction workers involved in building Refurbishment processes through a Software Application capable of using among others visible or InfraRed pictures of defects	H2020	01/06/2015	https://cordis.europa.eu/project/id/673802
D^2EPC	Next-generation Dynamic Digital EPCs for Enhanced Quality and User Awareness	H2020	01/09/2020	https://cordis.europa.eu/project/id/892984
DigiBUILD	High-Quality Data-Driven Services for a Digital Built Environment towards a Climate-Neutral Building Stock	HEUROPE	01/06/2022	https://cordis.europa.eu/project/id/101069658
ENCORE	ENergy aware BIM Cloud Platform in a COst-effective Building REnovation Context	H2020	01/01/2019	https://cordis.europa.eu/project/id/820434
IMIP	Innovative Eco-Construction System Based on Interlocking Modular Insulation Wood & Cork-Based Panels	INTERREG	01/05/2020	https://www.interreg-sudoe.eu/
INSITER	Intuitive Self-Inspection Techniques using Augmented Reality for construction, refurbishment and maintenance of energy-efficient buildings made of prefabricated components	H2020	01/12/2014	https://cordis.europa.eu/project/id/636063

MODERATE	Marketable Open Data Solutions for Optimized Building-Related Energy Services	HEUROPE	01/06/2022	https://cordis.europa.eu/project/id/101069834
Net-UBIEP	Network for Using BIM to Increase the Energy Performance	H2020	03/07/2017	https://cordis.europa.eu/project/id/754016
OptEEmAL	Optimised Energy Efficient Design Platform for Refurbishment at District Level	H2020	01/09/2015	https://cordis.europa.eu/project/id/680676
SEMERGY	Energy efficient and sustainable building planning	H2020	01/08/2015	https://cordis.europa.eu/project/id/697111

Table B.4 *H2020, Horizon Europe, Interreg and LIFE projects focused on financial, contractual and procurement aspects*

ACRONYM	EXPLANATION TITLE	PROGRAM	START DATE	LINK
C - R.E.A.L.	Creation of a holistic methodology for REnovation Advice with focus on Lending solutions differentiated by target group.	H2020	01/09/2020	https://cordis.europa.eu/project/id/890537
CitizEE	Scaling up Public Energy Efficiency Investments via Standardising Citizen Financing Schemes	H2020	01/05/2019	https://cordis.europa.eu/project/id/847147
CRREM	Carbon Risk Real Estate Monitor - Framework for science-based decarbonisation pathways, toolkit to identify stranded assets and push sustainable investments	H2020	01/02/2018	https://cordis.europa.eu/project/id/785058
easyCOPRO	Open book EPC for Brussels' condominiums	H2020	01/03/2018	https://cordis.europa.eu/project/id/785048
EBENTO	Energy efficiency Building Enhancement through performance guarantee Tools	HEUROPE	01/10/2022	https://cordis.europa.eu/project/id/101079888
EeDaPP	Energy efficiency Data Protocol and Portal	H2020	01/03/2018	https://cordis.europa.eu/project/id/784979
EENVEST	Risk reduction for Building Energy Efficiency investments	H2020	01/07/2019	https://cordis.europa.eu/project/id/833112
EFFECT4building	Effective Financing Tools for Implementing Energy Efficiency in Buildings	INTERREG	2017-10-01	http://www.interreg-baltic.eu/home.html
ENERFUND	An ENErgy Retrofit FUNDing rating tool	H2020	01/02/2016	https://cordis.europa.eu/project/id/695873
EnerSHIFT	Energy Social Housing Innovative Financing Tender	H2020	01/02/2016	https://cordis.europa.eu/project/id/694816
EUROPA	ENERGY EFFICIENCY SUBSCRIPTION FOR DEEP RENOVATION WITH PERFORMANCE GUARANTEE	H2020	01/10/2020	https://cordis.europa.eu/project/id/956649
EuroPACE	Developing, piloting and standardising on-tax financing for residential energy efficiency retrofits in European cities	H2020	01/03/2018	https://cordis.europa.eu/project/id/785057
FALCO	Financing Ambitious Local Climate Objectives	H2020	01/06/2017	https://cordis.europa.eu/project/id/747331
FinEERGo-Dom	Financing scheme for Energy Efficiency and Renewable energy Guaranteed in Deep renovations of building stock	H2020	01/06/2019	https://cordis.europa.eu/project/id/847059

FITHOME	An end-to-end solution accelerating cost-neutral retrofitting for energy-efficient family homes	H2020	01/05/2020	https://cordis.europa.eu/project/id/892214
GRASPINNO	Transnational model, strategies and decision support for innovative clusters and business networks towards green growth, focusing on green e-procurement in EE/RES for energy refurbishment of public buildings	INTERREG	2016-11-01	http://interreg-med.eu/en
GRASPINNO PLUS	GRASPINNO PLUS	INTERREG	2021-06-01	http://interreg-med.eu/en
GreenDeal4Buildings	National Roundtables to Implement the Smart Finance for Smart Buildings Initiative in Slovakia and the Czech Republic - GreenDeal4Buildings (Green Deal for Buildings)	H2020	01/06/2021	https://cordis.europa.eu/project/id/101032653
HIROSS4all	Home integrated renovation one-stop-shop for vulnerable districts	H2020	10/05/2019	https://cordis.europa.eu/project/id/846707
HousEEnvest	Energy Efficiency Investments in multifamily houses	H2020	01/03/2018	https://cordis.europa.eu/project/id/784986
INNOVATE	Integrated solutioNs for ambitiOus energy refurbishment of priVATE housing	H2020	01/06/2017	https://cordis.europa.eu/project/id/754112
LEMON	LEMON Less Energy More OpportuNities	H2020	01/02/2016	https://cordis.europa.eu/project/id/695863
LIFE CondoReno	Promoting Integrated Home Renovation Services models for condominiums	LIFE CET	O1/10/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101076316
LIFE EASIER	Supporting home renovations via a one-stop shop for technical services	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101077354
LIFE ENERGATE	Establishing a marketplace to accelerate investment in energy-efficiency renovations	LIFE CET	01/01/2023	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101076349
LIFE ENGAGE	Green mortgage financing for home energy improvements	LIFE CET	01/11/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101075995
LIFE FOSSTER	Flemish one-stop-shop for energy-efficient renovations	LIFE CET	01/12/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101076800
LIFE One stop Shop	Promoting home renovations for more energy-efficient buildings	LIFE CET	01/10/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101077212
LIFE OSR-Coop	Creating a one-stop building renovation cooperative	LIFE CET	01/10/2022	https://webgate.ec.europa.eu/life/publicWebsite/project/details/101076669
NEEM	Nordic Energy Efficiency Mortgages	H2020	01/06/2021	https://cordis.europa.eu/project/id/101025866
NEW FINANCE	New finance for energy efficiency measures in public buildings	INTERREG	2016-11-01	http://interreg-med.eu/en
NOVICE	New Buildings Energy Renovation Business Models incorporating dual energy services	H2020	01/06/2017	https://cordis.europa.eu/project/id/745594

ORFEE	Originating Retrofits Financing for Energy Efficiency	H2020	01/06/2020	https://cordis.europa.eu/project/id/894478
PadovaFIT Expanded	Expanding PadovaFIT! Home Solutions	H2020	01/06/2019	https://cordis.europa.eu/project/id/847143
PEER	Porto Energy ElevatoR	H2020	01/06/2021	https://cordis.europa.eu/project/id/101033708
ProRetro	Promoting building retrofits in the private residential sector through One-Stop-Shops in Germany	H2020	01/06/2020	https://cordis.europa.eu/project/id/894189
RenoBooster	RenoBooster - the Smart Renovation Hub Vienna	H2020	01/05/2019	https://cordis.europa.eu/project/id/847029
RenoHUb	Integrated Services to Boost Energy Renovation in Hungarian Homes	H2020	15/11/2019	https://cordis.europa.eu/project/id/845652
Ren-on-Bill	Residential Building Energy Renovations with On-Bill Financing	H2020	01/05/2019	https://cordis.europa.eu/project/id/847056
RenoWave	One-stop-shop extended model to increase the multi-apartment building stock renovation in the bsr	INTERREG	2023-01-01	https://interreg-baltic.eu/get-funding/programme-2021-2027/
RentalCal	Incentives through Transparency: European Rental Housing Framework for Profitability Calculation of Energetic Retrofitting Investments	H2020	01/03/2015	https://cordis.europa.eu/project/id/649656
RESCOOP MECISE	RESCOOPs Mobilizing European Citizens to Invest in Sustainable Energy	H2020	01/03/2015	https://cordis.europa.eu/project/id/649767
REVALUE	Recognising Energy Efficiency Value in Residential Buildings	H2020	01/03/2015	https://cordis.europa.eu/project/id/649705
Save the Homes	One-Stop Shops as Citizens' Hubs to support the decision making process for integrated renovations	H2020	01/09/2020	https://cordis.europa.eu/project/id/892749
SEIFA	Sustainable Energy Investing and Financing Activation	H2020	01/06/2021	https://cordis.europa.eu/project/id/101033741
SENSEI	Smart Energy Services Integrating the Multiple Benefits from Improving the Energy Efficiency of the European Building Stock	H2020	01/09/2019	https://cordis.europa.eu/project/id/847066
SER	Social Energy Renovations: Maximizing social impact and boosting clean energy investments in the non-profit sector through de-risking, aggregation, and capacity building	H2020	01/05/2021	https://cordis.europa.eu/project/id/101024254
SHEERenov	Seamless services for Housing Energy Efficiency Renovation	H2020	01/06/2020	https://cordis.europa.eu/project/id/890473
SMARTER	SMARTER Finance for Families– Improving Citizens' Health, Comfort and Financial Well-Being by Supporting Banks, Residential Investors and Solution Providers with Green Homes and Green Mortgage programs	H2020	15/05/2019	https://cordis.europa.eu/project/id/847141
STEPPING	Supporting The EPC Public Procurement IN Going-beyond	INTERREG	2016-11-01	http://interreg-med.eu/en
STEPPING PLUS	STEPPING PLUS	INTERREG	2021-03-01	http://interreg-med.eu/en
STUNNING	SusTainable bUsiNess models for the deep reNovation of buIldiNGs	H2020	01/10/2017	https://cordis.europa.eu/project/id/768287
SUNShINE	Save your bUildiNg by SavINg Energy – towards 202020m2 of deeply	H2020	01/03/2015	https://cordis.europa.eu/project/id/649689

	renovated multifamily residential buildings			
SUPER-HEERO	SUPERmarket Human based innovative financing schemes for Energy Efficiency Retrofitting and Optimisation	H2020	01/06/2020	https://cordis.europa.eu/project/id/894404
Superhomes2030	Superhomes 2030: Up scaling integrated Home Deep renovation services for Ireland	H2020	01/06/2020	https://cordis.europa.eu/project/id/890492
SUPER-i	Extended Public-Private Partnership for Investment in Smart Energy Efficiency Projects in a Social Housing context	H2020	01/09/2021	https://cordis.europa.eu/project/id/101028220
TIGER	Triggered Investments in Grouping of buildings for Energy Renovation	H2020	01/06/2021	https://cordis.europa.eu/project/id/101018403
TURNKEY RETROFIT	TURNKEY solution for home RETROFITting	H2020	01/06/2019	https://cordis.europa.eu/project/id/839134
C - R.E.A.L.	Creation of a holistic methodology for REnovation Advice with focus on Lending solutions differentiated by target group.	H2020	01/09/2020	https://cordis.europa.eu/project/id/890537
CitizEE	Scaling up Public Energy Efficiency Investments via Standardising Citizen Financing Schemes	H2020	01/05/2019	https://cordis.europa.eu/project/id/847147
CRREM	Carbon Risk Real Estate Monitor - Framework for science based decarbonisation pathways, toolkit to identify stranded assets and push sustainable investments	H2020	01/02/2018	https://cordis.europa.eu/project/id/785058
easyCOPRO	Open book EPC for Brussels' condominiums	H2020	01/03/2018	https://cordis.europa.eu/project/id/785048
EBENTO	Energy efficiency Building Enhancement through performance guarantee Tools	HEUROPE	01/10/2022	https://cordis.europa.eu/project/id/101079888
EeDaPP	Energy efficiency Data Protocol and Portal	H2020	01/03/2018	https://cordis.europa.eu/project/id/784979
EENVEST	Risk reduction for Building Energy Efficiency investments	H2020	01/07/2019	https://cordis.europa.eu/project/id/833112
EFFECT4building	Effective Financing Tools for Implementing Energy Efficiency in Buildings	INTERREG	2017-10-01	http://www.interreg-baltic.eu/home.html

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