White paper

Decarbonising residential buildings: A multi-stakeholder journey

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Foreword from ING

Putting sustainability at the heart of what we do is a priority of ING's overall business strategy. In a fast-changing world, where the physical impacts of climate change are intensifying, embedding sustainability into our business and seeking opportunities in the transition matters for ING, for our customers, for society and for the planet.

We have the ambition to play a leading role in accelerating the transition to a low-carbon economy, by supporting customers to drive down their emissions and by financing the technologies and solutions needed to build up a sustainable future. We do this by engaging with business clients to help them in their transitions, offering retail customers ways to reduce their carbon footprints, and by steering the most carbon-intensive sectors in our lending portfolio towards science-based net-zero targets.

The reality is that today a significant share of CO_2 emissions come from the built environment, and a significant share of that comes from people's homes. To achieve the global goals of the Paris Agreement, and to deliver on EU Member States' commitment to net zero, housing emissions across Europe must be reduced – and rapidly. In addition, addressing this challenge is a critical step for bringing people and society along in an inclusive and just transition.

While nearly all the required technology to decarbonise homes exists today, we still see major challenges preventing the sector from making faster progress. These challenges range from limited progress in greening the energy mix available to homes, the complexity and cost of home renovation, and a lack of clear government policy to guide the 'renovation wave' needed for a society-wide transition.

For ING, we take our part in this challenge seriously. In our retail business, we finance mortgages for homeowners across Europe. That gives us the opportunity to find new ways to enable them to make their homes more sustainable and future-proof. It can help to reduce their household expenditure, improve the comfort of their home and increase the value of their asset for the long term.

First and foremost, we know that for people to upgrade their homes for sustainability it must become more affordable. To assist with that, we offer mortgage customers incentives for renovations, and help them understand the costs of certain measures, the potential return that such measures can bring on energy savings, and how these improvements potentially increase their home's value. We also bring their awareness to available subsidies and financing.

We've also learned a lot about the practical hurdles people face in retrofitting for sustainability. The process is complicated and cumbersome. People don't know where to start, they don't know what's needed or how it all fits together, or how to find the contractors to do it for them. So, we focus on helping to simplify the process. As a start, we provide customers with access to renovation checks and platforms to guide their renovation journey. We're now able to arrange for an expert to visit a customer's home to develop a personalised plan for what will work best for their situation. Then, whether it's roof insulation, a heat pump or solar panels, we can connect customers with reliable contractors to get the job done.

While the actions of every individual and organisation matter, achieving the necessary shift requires systemwide solutions. There are many different stakeholders that must each play their role. That includes governments and utilities for greening the energy mix, policymakers and municipalities for subsidies and incentives, installation firms and contractors for the renovation and retrofitting implementation, and of course lenders that can help to finance such change when loans are needed.

We're exploring the potential of public-private mechanisms across the EU, working to help shape enabling policy at a national level, and building on our collaborations with municipalities in the Netherlands and across Europe. Our approach is based on working in partnership across the entire housing value chain to develop scalable solutions and to advocate for the policies and actions that can deliver meaningful progress.

We're excited to be stepping up our approach to sustainable housing. We want to make it the norm that upgrading a home automatically includes making it sustainable and future fit. That means earning our customers' trust by ensuring ING makes it affordable and easy for them to achieve their goals. We know that what we're doing now is a start, not an end point, but it gives us the chance to learn and scale up our impact over time. And we believe we can be a catalyst in moving the system towards homes that are sustainable today and into the future.

Through this white paper, we hope to contribute to the debate about where the sector is heading, the measures that can drive impact, and how we can all work together to make a difference in this critical sector.

Pinar Abay
Head of Retail Banking and member of the ING Management Board Banking

Executive summary

Achieving a net-zero economy is a global priority, as outlined in the Paris Agreement, but the challenges we face are already evident. To reach this goal, every individual, organisation, and government should take responsibility for the areas they can influence.

One sector that is currently not on track and is falling short of its net-zero scenarios is real estate[1]. At the same time, this sector is crucial to reach net zero as it accounts for 34% of European energy-related greenhouse gas (GHG) emissions[2]. The core challenge in decarbonising this sector, **particularly the residential building sector**, is that it requires the involvement of many stakeholders. The transition can be broken down into **on-site** measures, typically controlled by homeowners, and **off-site** measures, which are beyond such control. For off-site, the required key action is to decarbonise the energy supply, which requires many stakeholders, including utilities, to act. For on-site, the key actions are moving away from fossil-fuel-based heating systems like gas boilers and upgrading building envelopes, for which homeowners are key decision-makers. However, homeowners often lack expertise or financial capacity to make the necessary complex and costly changes to their properties and have yet to prioritise the required actions. Commercial banks aiming to decarbonise their residential building portfolio face this challenge.

Therefore, the question turns to '**What can stakeholders, including commercial banks, do to drive decarbonisation off-site and on-site** and create an environment where key decision-makers are motivated to implement these measures?'

This white paper explores a potential pathway for the residential building sector, **laying out what is necessary both off-site and on-site to have a chance of getting back on track** to a net-zero pathway. It examines how a multi-stakeholder approach can drive change and help influence the homeowner to make the right decisions with ease. The proposed pathway sheds light on the role of renovations and focuses on the most feasible renovation uptake. This paper explores the key stakeholders required to drive the transition in the building sector and, in particular, looks at the roles of governments, commercial banks, and homeowners. All have active roles in the transition and should be aiming to fulfil those.

To understand **what each stakeholder can do**, this white paper looks at the current state of residential building decarbonisation in **five European markets** (Belgium, Germany, the Netherlands, Poland and Spain), assesses their future decarbonisation pathways for the building stock in **three different scenarios** (Business-as-Usual (BAU), POLICY and NET-ZERO) to **quantify the existing emission gaps to net zero**, and **identifies a combination of decarbonisation measures required both off-site and on-site to reach net-zero**. The paper draws a comparison to the Carbon Risk Real Estate Monitor (CRREM) 1.5-degree country-specific decarbonisation pathways and the NET-ZERO scenarios elaborated for this white paper. While CRREM relies comparatively more heavily on on-site measures, the **NET-ZERO scenario proposes an alternative approach to achieving a net-zero decarbonised residential building sector**. This approach spreads the burden more evenly, combining ambitious on-site measures aimed at the building, with equally ambitious off-site measures focused on decarbonising the energy supply.

[1] Global Status Report | GlobalABC

[2] European Commission (2024) Building Stock Observatory, values for 2022

Analysing five different markets allows the assessment to cover a bandwidth of options and starting points. This exercise shows that while there is still a pathway to get to net zero, **a gap exists if we are to continue on the status quo** (BAU scenario) or if a scenario based on limited implementation of policy would take place (POLICY scenario). Hence, moving toward the path to net-zero requires a lot more from all stakeholders, including policymakers, than current efforts (see Figure 1).

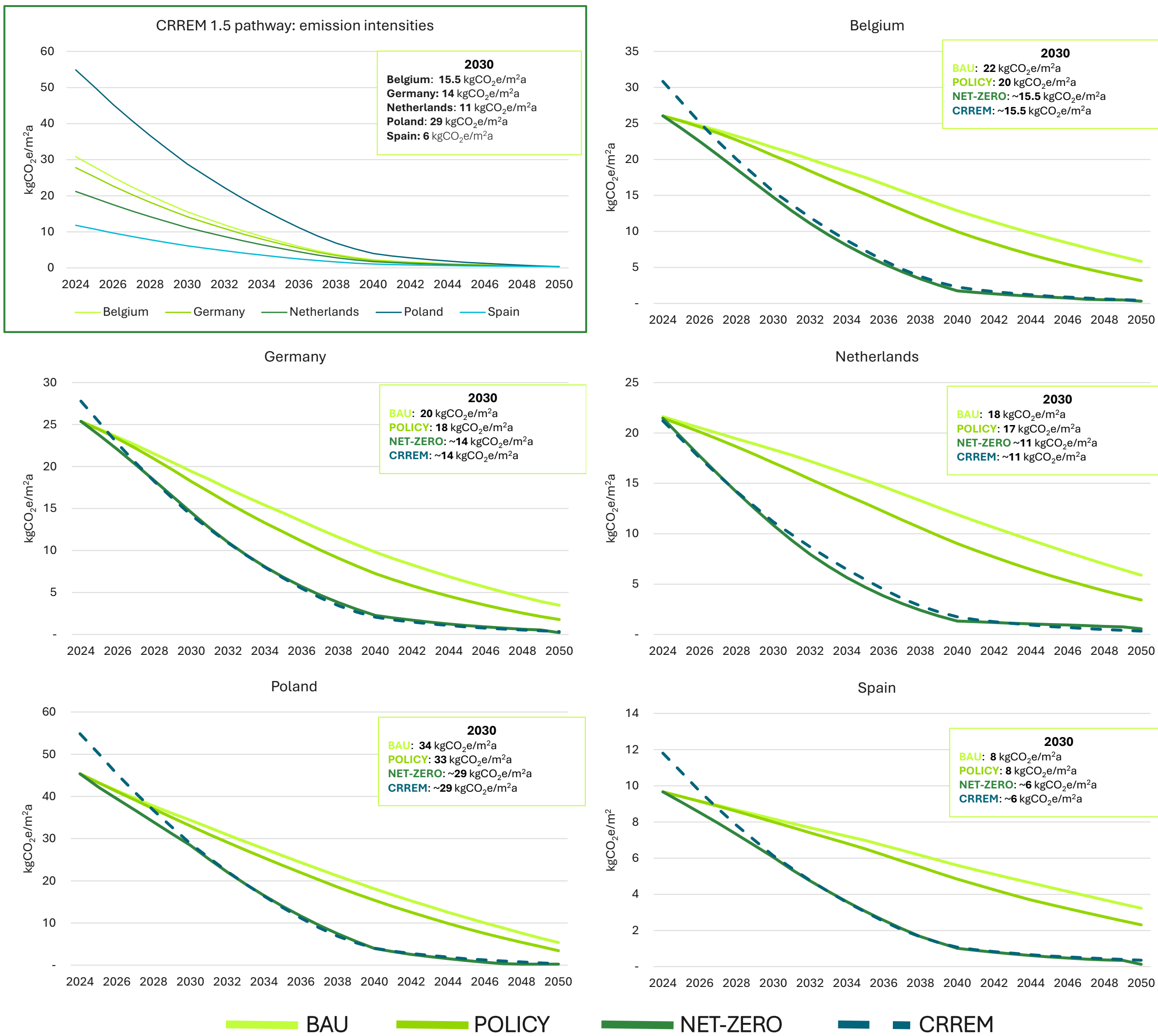

Figure 1: GHG-emission intensities per scenario, modelled against the CRREM 1.5 decarbonisation pathway across the assessed markets

The modelled results for the NET-ZERO scenario show that closing this gap can be achieved via a combination of the following four technical decarbonisation measures:

Off-site	On-site
• Measure 1: Greening the energy supply via: ○ Decarbonising the electricity grid ○ Decarbonising district heating networks ○ Uptake of biofuels and phase-out of natural gas	• Measure 2: Deeper building envelope renovations • Measure 3: Heating system upgrade and the uptake of heat pumps • Measure 4: Higher insulation standards and high-performance buildings (new buildings)

The markets assessed are at differing stages of progress in terms of initiating residential building decarbonisation measures. This is reflected in the different prioritisation of these measures per market[3].

Off-site measures for greening the energy supply and in particular its sub-measures have different importance across each market. For instance, the uptake of biofuels is of potentially higher importance for the Netherlands due to the highest dependency on natural gas and the ongoing discussion about the possibility of switching to biofuels like biomethane with minimal adjustments to the existing systems. Decarbonising the electricity grid is of the highest relevance for Poland where the current electricity grid emissions are significantly higher than the other markets and would hinder the full benefits of electrification.

Furthermore, on-site measures like higher insulation standards and high-performance buildings as well as heating system upgrades are crucial to reduce energy demands. This would be especially evident in countries like Spain, which have already made progress on greening their energy supply.

In all five markets, significantly speeding up current progress on the identified measures, as outlined in the POLICY scenarios, is essential to reaching net zero by 2050. **To close the identified gap with the NET-ZERO scenario, close collaboration of the key stakeholders** – commercial banks, governments and regulators, homeowners (institutional and individual), housing associations, developers, land developers and private landowners, installers, manufacturers, media, national energy system operators, tenants and utilities – **is indispensable, and strongly needed** to master the extraordinary challenge at hand. Each of them can enable the implementation of the identified decarbonisation measures through policy and regulatory, technological, social and economic drivers. The paper describes **which stakeholder needs to act and how, on which measure**, and clarifies how collaborative efforts among different stakeholders are essential to achieve residential buildings decarbonisation.

The level of influence for each stakeholder is different for the four identified technical measures. Next to one or two key decision-makers, often homeowners, this white paper identifies **governments and regulators as crucial influencers of investment decisions** across all four measures. This is because they are in charge of and responsible for all categories of policy

[3] See Annex 5.4 for further details on the analysis criteria which were used for evaluating the measures relative importance across the five markets.

measures, which help create, multiply or enforce triggers, mitigate or remove barriers, and create, multiply or enforce drivers. Additionally, **commercial banks have considerable influence** by financing the required transition and facilitating stakeholder collaboration.

The newly revised Energy Performance of Buildings Directive (EPBD) marks a significant shift in the requirements for Member States. While the current building stock and current policies rather mirror past EPBD editions, the revised EPBD has yet to be transformed into new policy frameworks, namely National Building Renovation Plans (NBRP), and then enforced for getting national building stocks to zero-emission level by 2050. **Many recommendations made in this paper find a corresponding starting point in the revised EPBD.** With Member States required to transpose the revised EPBD into national law by May 2026, and submit draft NBRPs for achieving zero emissions by 2050 by the end of 2025, now **is the time for governments to fully embrace this transition.** By engaging all relevant stakeholders, they must make well-aligned, acceptable decisions on the right policy measures and their enforcement.

A key takeaway of this white paper is that meaningful onboarding of relevant stakeholders for such decision-making about **residential building decarbonisation requires a holistic ecosystem approach** to align the goals, resources, and expertise of the key stakeholder groups, i.e. to create their buy-in, acceptance and continued support. This will help create synergies and a favourable environment to make decisions happen and overcome barriers like high costs, lack of awareness, and fragmented efforts. Collaboration ensures that every part of the system contributes effectively, enabling faster and more widespread adoption of decarbonisation measures.

Within such an ecosystem approach, **it is essential that governments fully take on their responsibility assigned by the revised EPBD**, using the full set of policy measures – regulation, economic promotion and information – in the best possible way to design a policy framework that delivers, and involves all relevant stakeholders as explicitly required in the EPBD.

At the same time, **commercial banks play an active role in financing the required transition and facilitating stakeholder collaboration**. In particular, they should pursue the following action items to contribute to the acceleration of the residential building decarbonisation.

- **Making renovation more affordable:** Commercial banks can explore innovative mechanisms and products to make renovation more attractive to customers. This includes assessing the impact of pricing to strengthen the business case and leveraging public-private blended finance instruments.
- **Making it easier to renovate:** Commercial banks can help homeowners navigate the information and decision process on deep renovations by developing and aligning ecosystem-based renovation platforms and support services.
- **Collaborating with stakeholders and leveraging of networks:** The influence of commercial banks extends beyond financing, as they can serve as facilitators and connectors by leveraging their networks and aligning incentives to support an ecosystem approach.

As a potential format to foster collaboration, innovation and actionable progress, **centralised platforms for residential building decarbonisation** could be established (or strengthened at national level where bodies partially exist), uniting key stakeholders from the built environment to jointly define and advance action. The main components could cover **roundtables to facilitate the definition of required actions and corresponding plans**; working groups for each of the key technical decarbonisation measures defined with all respective stakeholder groups; and a centralised knowledge hub with tailored services and materials based on learnings from existing one-stop shop initiatives to make the renovation journey more accessible.

A key objective of such a platform for residential building decarbonisation would be to jointly define a shared path forward, such as issuing a **joint commitment** or statement **to accelerate progress and ensure advancement towards net-zero**. This would ideally be enshrined in and aligned with the NBRPs. The commitment should highlight the need for all key stakeholders to jointly act together as the corresponding responsibilities and actions are closely interlinked. To use the momentum, involvement of senior-level sponsors would be a prerequisite to also ensure political buy-in. Such a centralised ecosystem platform would serve as a cornerstone to drive collective progress, enabling commercial banks to play an active role in bringing together diverse stakeholders to unify efforts, foster innovation, and define a shared, actionable pathway towards accelerating residential building decarbonisation.

1. The imperative for decarbonising residential buildings

Following the adoption of the Paris Agreement, the reduction of greenhouse gas (GHG) emissions has become a policy priority for nations, businesses, and regions like the European Union (EU) globally. The EU aims to be climate-neutral by 2050. To achieve this target, strong decarbonisation efforts are required in the building sector, which is a key contributor to GHG emissions in the EU, representing 34% of energy-related emissions in 2022[4]. The EU has the overall target to reduce GHG emissions by 55% by 2030[5] and requires new buildings to be carbon neutral. More importantly, existing buildings must be upgraded. To achieve these climate goals for the built environment, significant emission reductions can come from residential buildings[6,7], particularly from measures both off-site and on-site.

The final energy consumption of EU households stems from space heating (63.5%), water heating (14.9%), lighting and appliances (13.9%), cooking (6.3%), space cooling (0.6%), and other end uses (0.9%)[8]. This emphasises the significant role buildings renovations can play as they directly influence the two major consumption sources (space and water heating). The building sector's significant contribution to the EU's GHG footprint highlights the need to accelerate the average building renovation rate, which currently stands at around 1% each year across EU27 markets[9]. This white paper assesses the current emissions gap to a NET-ZERO scenario (see Chapter 2) and explores a possible solution to close the gap (see Chapter 3), highlighting the need for a multi-stakeholder approach (see Chapter 4).

The main policy instrument to drive building decarbonisation is the Energy Performance of Buildings Directive (EPBD). Because of the EU building stock's decarbonisation so far not at all being in line with climate target-leading pathways, for the first time, in its major May 2024 revision[10], the EPBD explicitly refers to the legally binding objective of reducing GHG emissions in the EU by at least 55% by 2030 compared to 1990 and achieving climate neutrality by 2050 at the latest. Consequently, the EPBD's subject matter now refers to 'achieving a zero-emission building stock by 2050'. Both new concepts of 'zero-emission buildings' and a 'zero-emission building stock' serve as overarching guiding principles for EU Member States' full transposition of the EPBD into national legislation by the end of May 2026.[11] Technically, 'zero-emission buildings' need to be achieved by both on-site and off-site measures. A comprehensive set of

[4] European Environment Agency (2024), Greenhouse gas emissions from energy use in buildings in Europe, https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-energy

[5] European Commission (2024), Buildings and construction, https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2030-climate-targets_en

[6] ING (2024), Herverdelingseffecten verduurzamingsnorm woning minder nadelig voor lage inkomens dan gasbelasting, https://www.ing.nl/zakelijk/economie/woningmarkt/herverdelingseffecten-verduurzamingsnorm-woning-minder-nadelig-voor-lage-inkomens-dan-gasbelasting

[7] Within the built environment in the Netherlands, for example, approximately 70% of GHG emissions come from homes.

[8] Energy consumption in households - Statistics Explained

[9] Esser, Anne; Dunne, Allison; Meeusen, Tim; Quaschning, Simon; Wegge, Denis; Hermelink, Andreas et al. (2019), Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU. Final report. Research report prepared for European Commission, DG Energy. Ipsos; Guidehouse (formerly Navigant), https://op.europa.eu/en/publication-detail/-/publication/97d6a4ca-5847-11ea-8b81-01aa75ed71a1/language-en/format-PDF/source-119528141,

[10] For a detailed overview of new provisions, please cf. the original text of EPBD 2024.

[11] EU Member States have until 29th May 2026 to transpose the regulation into national law[11], except for a 2024 prohibition on any financial incentives for fossil-fuel boilers, which must be transposed into national laws by 1 January 2025.

new and updated provisions requires Member States to create an environment that ensures the actual implementation of necessary measures in both new and existing buildings. Banning Member States' financial incentives for the installation of stand-alone fossil-fuel boilers from 1 January 2025 onwards is one prominent example, highlighting that the revised EPBD mandates more targeted financing for investments in the decarbonisation of existing buildings, complementing other EU instruments (such as the European Green Deal[12] or Fit for 55[13]) and fighting energy poverty by supporting vulnerable consumers.

Mandatory Minimum Energy Performance Standards (MEPS) is the best-known policy instrument that has been introduced with the revised EPBD. In this context, among others, Member States need to determine the energy performance threshold, where on 1 January 2020, 26% of the national non-residential buildings performed worse, and then make sure that by 2033 all non-residential buildings will remain below that threshold. De facto, this implies the obligation to improve the energy performance of each building that is part of those worst performing 26%.

So far, the EPBD poses no such direct obligation for individual worst-performing residential buildings. This is because Member States insisted on having more flexibility with regards to suitable policy instruments. Instead, the EPBD requires Member States 'to establish a national trajectory for the progressive renovation of the residential building stock … with the aim of transforming the national building stock into a zero-emission building stock by 2050' and concretely requires to decrease the average primary energy use 'of the entire residential building stock … by at least 16% compared to 2020 by 2030 … and 20-22% … by 2035', and by a level in line with the 'zero-emission residential building stock' objective for 2040, 2045 and 2050. A total of 55% of those decreases must stem from the 43% worst-performing residential buildings. While member state governments in principle are free to set up the mix of policy instruments, they need to justify and document it, in so-called National Building Renovation Plans (NBRP), and they have to consult stakeholders while drafting their NBRP. This is a major starting point for this paper, as it will both analyse which technical on-site and off-site measures are needed to achieve a zero-emission building stock by 2050, and what stakeholders need to do to seize the opportunity provided by the new EPBD to get on a net-zero pathway.

Large investments are required to transform the EU building sector to net-zero emissions. Currently, building renovation has one of the most considerable investment gaps in the EU, with estimates showing €275 billion of additional investment required in yearly building renovation in the period between 2020-2030 to achieve the 55% GHG emission-reduction target of the EU Renovation Wave by 2030 compared to 1990 levels[14,15]. The financial sector is one of the key stakeholders in enabling this through their mortgage portfolios, as they are well placed to influence mortgagors at critical trigger points, such as home purchases, renovations, or re-mortgages. Decarbonisation of mortgage portfolios is a significant lever towards overall climate targets for banks.

For ING, as for many commercial banks, mortgages represent a substantial portion of lending, making the impetus for mortgage portfolio decarbonisation significant. Banks have already

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[12] European Commission (2024), The European Green Deal, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[13] European Council (2024), Fit for 55, https://www.consilium.europa.eu/en/policies/fit-for-55/

[14] European Commission (2023), Investments in the sustainability transition: leveraging green industrial policy against emerging constraints, https://www.eea.europa.eu/publications/investments-into-the-sustainability-transition

[15] Climate Strategy & Partners (2023), Engaging Retail Lenders in Home Renovation – Renovation Finance Report, https://www.climatestrategy.es/press/2023RenovationFinanceReport.pdf

begun implementing efforts to decarbonise their mortgage portfolios as a way to operationalise their overall climate targets[16], yet gaps are emerging between climate scenarios and the decarbonisation pace of the residential building stock.

As seen above, current measures for residential building decarbonisation do not go far enough. Many European banks that are members of the Net Zero Banking Alliance (NZBA), including ING, have some form of voluntary Mortgage Portfolio Standard (MPS) in place already. However, those forms of standards can vary significantly across scope, ambition level, transparency of disclosures, and maturity of implementation. For example, targets among NZBA members for real-estate emissions reductions by 2030 were highly variable and ranged from only 8% to 75%[17]. This results in a very large range between the banks stepping up to support the transition of this critical sector of society and those that are not taking considerable steps. Moreover, the reduction of this range is targeted by the revised EPBD, by requiring the European Commission to develop a portfolio framework for voluntary use by financial institutions, which is in line with the target of a zero-emission building stock by 2050.

To accelerate decarbonisation to progress towards net zero, sustained efforts are required. Residential building decarbonisation efforts must combine on-site initiatives, such as deep building renovations (associated with space heating, water heating, lighting and appliances, cooking, other end uses, and space cooling), and off-site initiatives, such as power system/energy mix decarbonisation. The responsibility of driving this decarbonisation sits with a wide ecosystem of stakeholders with access to a variety of drivers. The financial influence that banks have is one of the key drivers for residential decarbonisation. However, to unlock that financing, more is needed to incentivise demand among homeowners where it currently lags. That demand from homeowners, whether self-inspired due to an improving business case of renovations, or mandated through NBRPs by government, needs to be supported by an ecosystem of stakeholders that are further improving the business case, and making the whole process easier for homeowners.

[16] Climate Strategy & Partners (2024), Response to the European Banking Authority's Consultation on Draft Guidelines on the management of ESG risks, https://www.eba.europa.eu/system/files/webform/webform_consultation_16620/75214/EBA_Climate%20Strategy%20%26%20Partners_April_15_2024.pdf

[17] Net-Zero Banking Alliance (2024), 2024 Progress Report, https://www.unepfi.org/wordpress/wp-content/uploads/2024/10/NZBA-2024-Progress-Report.pdf

2. Determining the gap: A scenario-based comparison

Given the importance of decarbonising the residential building stock, this chapter quantifies and dives into the emission gaps between three different decarbonisation pathways (BAU, POLICY and NET-ZERO) across five European markets (Belgium, Germany, the Netherlands, Poland and Spain) that are in the focus of ING. This paper uses the Built Environment Analysis Model (BEAM^2)[18] to analyse and quantify the final energy- and GHG emissions intensities across the three different scenarios and draw comparison to the Carbon Risk Real Estate Monitor (CRREM) decarbonisation pathways (see Annex 5.1 for BEAM^2 model description and methodology). The chapter concludes with a presentation of the quantified results along with gap analyses and assessment across the modelled scenarios and the CRREM decarbonisation pathway.

Impacts are assessed based on both the ‘renovation depth’ (characterising the percentage of savings achieved through certain measures applied in the homes), and the ‘renovation rate’ (the speed of implementation of such measures within the housing stock)[19]. For the sake of a more realistic scenario analysis and allowing for full exploitation of the available data, the housing stock is segmented into three common residential building types, and then renovation measures (depth) and rate are defined and assessed distinctly by type (see Box 1).

Box 1: Building types and renovation depth / rate

The building types discussed are[20]:

- Single-family homes (SFH): detached or semi-detached dwellings intended for single households.
- Small multi-family homes (SMFH): consist of several dwellings in one building (low/mid-rise), commonly designed to house multiple families.
- Large multi-family homes (LMFH): high-rise buildings that contain several dwellings and have more than six storeys.

Renovation depth	**Renovation rate**
This describes the primary energy demand savings compared to the calendar year before the energy renovation and can be classified as: • Below threshold: <3% reductions • Light: 3-30% reductions • Medium: 30-60% reductions • Deep: >60% reductions	This describes the pace at which building stock floor area undergoes renovations to improve energy performance as a function of the total building stock.

[18] A detailed bottom-up building stock assessment model has been set up in the framework of the impact assessment leading to the European Commission’s proposal for the revised Energy Performance of Buildings Directive EPBD. It has been adapted for the purpose of this White Paper.

[19] European Commission et al (2019). Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU – Final report. https://data.europa.eu/doi/10.2833/14675

[20] EU Building Stock Observatory

2.1 Current state and scenarios definitions

2.1.1 Current state

Renovation rates across the EU are lagging behind what would be required to meet a net-zero building stock by 2050 and are currently estimated to be around 1%. This rate differs across EU Member States where some are performing slightly better than others. Across the five assessed markets, only Germany seems to come close to the EU average of 1%[21]. Furthermore, inefficient buildings are widespread and constitute a large share of the building stock across the EU. This also holds true for the five assessed markets, as a result of varying national policies, regulations and historical building standards.

Currently, fossil fuels and specifically natural gas are the most dominant source of heating across the EU and across the five assessed markets (with the exception of Poland where natural gas holds the second place after coal).[22] This is evident in the continued reliance on fossil-fuel boilers and the slow rate of exchange with efficient and renewable heating sources. Beyond the boundaries of the building stock, electricity grid readiness plays a pivotal role in the future decarbonisation pathways and currently the share of renewable energy in electricity varies significantly across the five markets.[23] A detailed breakdown of the current state of national policies and legislations that were used to inform each of the modelled scenarios for all five assessed markets are provided in the country deep dives in Annex 5.2.

2.1.2 Scenarios: definition

Scenarios are used in this paper to describe a path of development leading to a particular outcome (e.g., building decarbonisation). These scenarios are not intended to represent a full description of the future, but rather to highlight central elements and to draw attention to the key on-site and off-site measures (see Box 2 for on-site and off-site definitions) that will drive future developments. In a world of uncertainty, scenarios are intended to explore alternatives that may significantly alter the basis for 'business-as-usual' assumptions. The three different scenarios (BAU, POLICY, NET-ZERO) are defined in the Table 1 below.

[21] If there is any information available about renovation rates, it is noteworthy that, so far, EU Member States do not use comparable methodologies for determining or estimating these rates. The revised EPBD and the European Commission's implementing regulation on NECP progress reports aims to harmonise the methods used to determine renovation rates.

[22] For more details see Table 8.

[23] Share of renewable energy in electricity 2023: BE 31.4%; DE: 52.2%; ES: 56.9%; NL: 46.4%; PL: 25.8%.

Table 1: Scenarios definition

BAU	This scenario is based on trends from sources such as recent EU Building Stock Observatory[24] (BSO) data and extrapolations of historical renovation rates and grid energy mix changing over the past five years. Actual implementation of national policies has been approximated as far as useful, while recognising that current government plans, ambitions, incentives, and enforcement can result in lower impact than envisaged. The impacts of limited enforcement are modelled in this scenario to show what would occur in this case. Concretely, the BAU scenario does not yet include assumptions about a potentially ‘weak’ future implementation and/or enforcement of the latest EPBD 2024 in the respective national context.
POLICY	This scenario looks at current government policy until the end of 2026 with full regulatory compliance, and subsequently the previous EPBD policy impacts as translated into national legislation. This includes policy for both energy efficiency improvements as well as for power and district heat generation and decarbonisation. Recent EPBD requirements of the 2024 revision are not modelled throughout this paper for several reasons: so far, especially for the above-mentioned ‘trajectories’ for residential buildings, member state governments are figuring out how to define and subsequently translate into national policy instruments. Furthermore, as the POLICY scenario here is meant to represent full compliance and enforcement, a fully compliant and enforced implementation of the EPBD 2024 should be in line with a net-zero scenario. Assuming a POLICY pathway that already considers the full implementation and enforcement of the EPBD 2024 could create the illusion that this drastic step change might be easy for national governments to achieve. However, given the implementation of previous generations of the EPBD, this does not seem very likely (see the difference between the POLICY scenario modeled here and the BAU scenario). One highly ambitious implementation and enforcement of EPBD 2024 therefore is reflected in the NET-ZERO scenario. POLICY takes into consideration planned measures as highlighted in national policies. This scenario only models national policies in so far as there are explicit measures defined or announced as part of those policies. *The key difference between the BAU and POLICY scenario is the actual level of implementation and enforcement. Beyond the design of policy packages and measures, this was considered as most relevant.*

[24] EU Building Stock Observatory

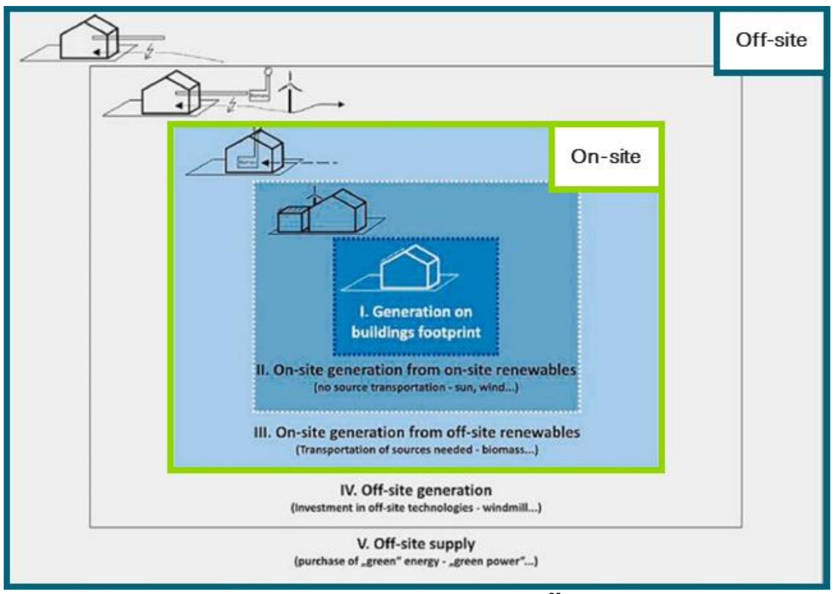
NET-ZERO	This scenario explores further on-site and off-site measures and actions that are needed to align with a net zero-pathway that closely tracks the decarbonisation *outcomes* expected under the CRREM 1.5-degree pathway. This scenario takes into consideration planned and expected measures because of policies and supplementary measures that are not yet defined on market levels. This scenario assumes that current policies are not sufficient to align with the CRREM decarbonisation pathways and therefore is constructed using a different combination of technical measures that policymakers and other stakeholders could trigger by suitable (policy) instruments or actions to reach net zero outcomes closely in line with CRREM. As mentioned above, the NET-ZERO scenario could be interpreted as one possible highly ambitious, even if not necessarily 'optimal', implementation *and* enforcement of EPBD 2024. *The modelled NET-ZERO scenario represents just one possible way, and it is neither deemed to be the only or most feasible nor the cost-optimal approach to reach a decarbonised residential sector. Further sensitivity assessment is needed, along with an evaluation of economic and social aspects, to identify a just, feasible approach to decarbonise the residential sector.*
CRREM decarbonisation pathways (Benchmark – not modelled)	This benchmark reflects the science-based 1.5 degrees net-zero pathway as informed by global carbon budgets, using the (CRREM) national average for each focus market. CRREM uses GHG emissions (and energy consumption) divided by floor area coverage to determine an individual asset's intensity-based transition pathway. This details how specific assets need to become more efficient to align with certain transition scenarios. Each pathway extends to 2050 and is composed of annual trajectories of building-related carbon and energy intensities, expressed in kWh per m^2 and CO_2 per m^2, respectively.

Box 2: On-site vs Off-site

‘On-site’ according to the latest EPBD revision (2024) is defined as follows: *‘On-site’ means in or on a particular building or on the land on which that building is located*[25]. In the context of this paper, homeowners are the key decision-makers when it comes to on-site technical measures, such as the installation of heat pumps or thermal insulation of the building envelope.

Off-site refers to the boundaries and technical measures taking place beyond on-site as defined above. Other stakeholders, such as utilities, are the key decision-makers for off-site measures in the context of this paper.

The following graphic provides an overview on the boundaries of on-site and off-site when it comes to energy generation.



Adapted from Marszal et. al 2011[26]

2.2 Scenarios: parameters and assumptions

Based on the scenario definitions, several key parameters were assessed to identify the gaps between those scenarios and how they translate into achieving decarbonisation goals for residential buildings. Among those parameters, the most critical to this assessment were renovation rate and renovation depth, including the heating system *rate* of exchange, and the type and efficiency of the new heating system compared to the replaced system (*depth*).

2.2.1 Renovation rate and renovation depth

The current renovation rates (focused on on-site measures) across the five assessed markets are currently far below the levels that would be required to reach any market-specific decarbonisation goals. However, there are limits to what can realistically be achieved as a

[25] EPBD 2024, Art. 2

[26] Marszal et al. (2011), Zero Energy Building – A review of definitions and calculation methodologies

maximum for renovation rates without exceeding technically, socially, and financially feasible tipping points for affected stakeholders. Here, it is set to about 3% of total floor area per year.[27] The following Table 2 provides an overview of the assumed renovation rates for each of the modelled scenarios for each of the assessed markets.

Table 2: Assumed renovation rates per modelled scenario and per assessed market[28]

Market	Renovation rate (% of total floor area)						
	Base year (2024)	BAU		POLICY		NET-ZERO	
		2030	2050	2030	2050	2030	2050
Belgium	1.0%	1.2%	1.3%	2.0%	2.2%	3.0%	3.3%
Germany	1.1%	1.5%	1.5%	2.2%	2.5%		
Netherlands	1.0%	1.4%	1.4%	2.1%	2.5%		
Poland	1.0%	1.5%	1.5%	2.0%	2.5%		
Spain	0.8%	1.1%	1.4%	2.2%	2.2%		

The current efforts and policies are recognised for each of the assessed markets and reflected on each of the modelled scenarios as per scenarios definitions. The key assumption being that energy-related renovations will be widespread and coupled with most renovation activities that so far concerned non-energy related renovations (e.g. regular home upgrades and maintenance) across the EU. A major shift from light renovations achieving 15% of final energy savings on average towards medium renovations with energy savings of around 50% across all scenarios is assumed, building on the results of what is needed and what is realistic from two comprehensive Guidehouse studies that were previously conducted for the European Commission.[29] In addition, an increasing focus on deeper renovations achieving up to 80% energy savings for the POLICY and NET-ZERO scenario is estimated, with the key difference being the increased number of renovations as a result of the varying renovation rates. Market specific assumptions are provided in Annex 5.2 in the country deep dives. Figure 2 provides an exemplary breakdown of the actual renovation works across the three renovation depths.

[27] In the impact assessment leading up to the European Commission's proposal for EPBD 2024, 3% turned out to be the maximum realistic renovation rate that would not result in an over-burden on any of the assessed parameters (e.g. availability of supply chains, public acceptance, financial support, burden to the electricity grid) in each of the five European zones – East, West, North, North-East, South-East – that were assessed in depth.

[28] In general, there seem to be significantly higher renovation rates than the maximum of about 3% assumed here, which shows significantly higher average annual reduction rates of energy intensities between our NET-ZERO scenario and CRREM (cf. Figure 4).

[29] European Commission: Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU and EPBD Impact Assessment.

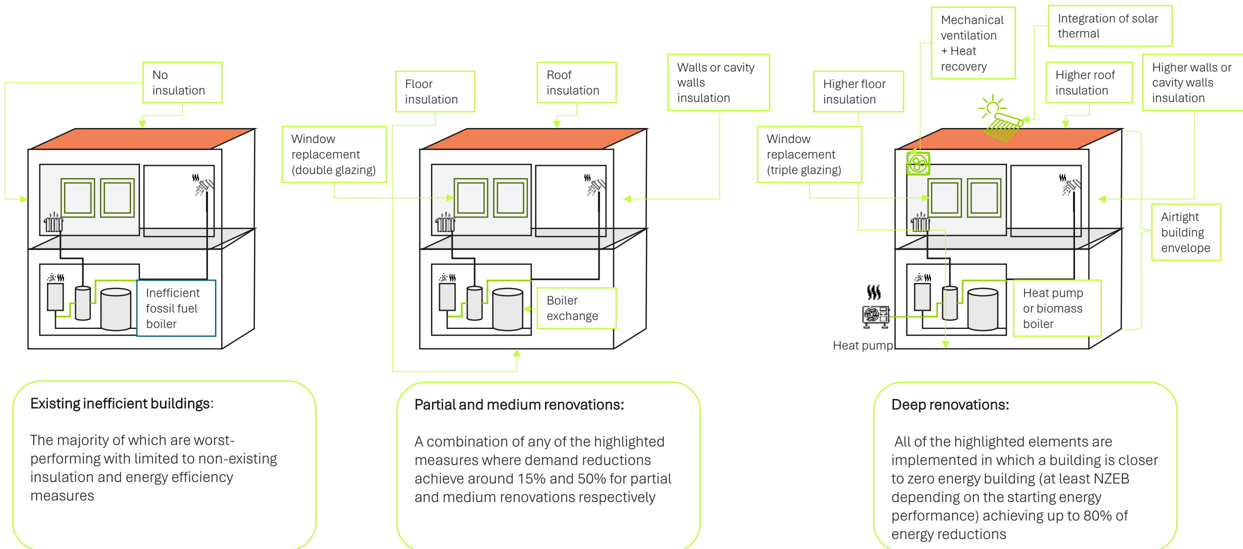


Figure 2: Renovation works per renovation level for a reference building

2.2.2 Heating systems and heating systems exchange

Heating systems are key factors in assessing the overall final energy consumption and achieving residential building stock decarbonisation. Each modelled scenario assumes a new mix of heating systems exchange according to their definitions. The transition focus and heating-system exchange rate is centred around the adoption of heat pumps, as they play a pivotal role in driving the decarbonisation efforts by significantly reducing the energy demand and the corresponding emissions (see Box 3 for further information on the importance of heat pumps in residential building sector decarbonisation). Table 3 provides an overview of the assumed heat pump annual uptake rate of the total heating system's installations on average across the five markets.

Table 3: Assumed share of heat pumps within total installations of new heat generators in residential buildings

Scenario	Year		
	2030	**2040**	**2050**
BAU	30%	35%	40%
POLICY	45%	50%	55%
NET-ZERO[30]	45%	50%	55%

[30] This scenario targets a larger share of heat pumps in the overall heating systems stock than POLICY scenario as it is a function of renovation rate.

Box 3: The role of heat pumps in decarbonising the residential sector

Heat pumps are pivotal in decarbonising the residential building sector. If designed and implemented well, heat pump heating systems have exceptional energy efficiency. In the future, they will run on 100% renewable electricity. By utilising renewable, low-temperature ambient heat sources such as the ground, ground water or air, heat pumps can deliver up to six units of heat for every unit of electricity. Unlike conventional new fossil-fuel boilers that deliver approximately one unit of heat per unit of purchased fossil fuel, heat pumps significantly reduce the amount of final energy needed. Moreover, the higher the efficiency of the heat pump, the greater the potential for substantial reductions in heating bills.[31]

To maximise the impact of heat pumps, when paired with renewable electricity, heat pumps effectively decouple heating from carbon emissions, enabling substantial reductions in GHG outputs. Heat pumps work best with (very) low-temperature heating systems. To prevent excessive electricity use and peak loads on the grid, homes should be retrofitted with adequately improved building envelopes. Without these improvements, widespread heat pump adoption could require significant additional increases in electricity generation, storage capacity, renewable integration, and grid stability measures all of which would drive up costs.

The BAU scenario relies on projections of the current heating systems exchange rate from the sales and stock development, leading to a slow replacement and continued high reliance on fossil fuels. For example, the current heat pump adoption rate is around 10-15% of new sales of heat generators on average across the five markets.

For the POLICY scenario, all regulatory bans and restrictions of heating system installations and fuel use are considered with full compliance, along with any current policies in place that have clearly defined measures for the uptake of a certain heating system. It is assumed that a moderate share of heat pump increase is to take place across all five assessed markets along with an increased focus on district heating connections where applicable. This scenario targets a timely replacement of heating systems as per planned policies and regulations.

The NET-ZERO scenario assumes the same exchange rate of heating systems to heat pumps across the five markets as the POLICY scenario targeting 45%, 50%, and 55% by 2030, 2040 and 2050 respectively. However, mainly due to the higher renovation rate compared to the POLICY scenario, this happens within a higher absolute number of heat generator replacements, leading to a higher absolute number of newly installed heat pumps.

2.2.3 GHG emissions development

Across all five markets, the EU Fit-for-55 package 2040 climate target plan was used as a basis for the estimation of electricity grid emissions development, district heating decarbonisation and the uptake of biofuels. The BAU and POLICY scenarios are aligned with policy target option 1[32], which aims for a net GHG reduction target of 80% by 2040 compared to 1990 levels. The NET-

[31] Example: assuming a price of 24 ct/kWh for electricity, and 8 ct/kWh for gas, this is a ratio of 3.0. If the ratio between the seasonal energy performance of the heat-pump heating system and the efficiency of the alternative gas heating system is higher than that ratio, e.g. 3.8, the energy bill decreases. The higher the heat-pump system's efficiency, the more the heating bill will decrease.

[32] This target option is compatible with a linear trajectory of net GHG emissions between the existing 2030 climate target and the 2050 climate-neutrality objective referred to in the Climate Law (Article 8). It assumes a limited remaining CO_2 emission in 2040, share of renewables in total electricity production increases compared to 2030.

ZERO scenario was based on policy target option 2[33], which aims for a net GHG reduction target in 2040 of at least 85% and up to 90% compared to 1990 levels. Further details, assumptions and feasibility of both pathways are provided in the FF55/2040 climate target plan[34].

2.3 Scenario results and gap assessment

The decarbonisation of the residential sector requires a dual approach that addresses actions needed at two levels, on-site and off-site.

2.3.1 On-site

On-site measures drive reductions in energy demand and are generally shaped by building envelope improvements and heating systems exchange to more efficient, and sustainable systems. The achievable energy demand savings are highly dependent on the rate of renovation and the depth of renovation activities performed at the whole building level (e.g. from light to deep renovations). They are also influenced by the heating systems exchange rate and the type of heating system installed.

Renovated floor area

As a result of the identified renovation rates, the average renovated floor area of the existing total floor area across all three scenarios and assessed markets is depicted in the following Table 4.

Table 4: Average share of renovated floor area per scenario across all five markets

Scenario	Year		
	2030	**2040**	**2050**
BAU	7%	20%	35%
POLICY	10%	30%	50%
NET-ZERO	13%	45%	80%

These figures highlight the noticeable contrast in ambition and effectiveness among the scenarios, underscoring the substantial scale-up in renovation efforts required to align with a net-zero pathway.

Heating systems stock

Heating system stock change is highly dependent on the market context and common heating systems practices, technology availability, and political frameworks. Nonetheless, heat pumps are an integral part of the decarbonisation, and a key enabler of the decarbonisation under any scenario. Figure 3 provides an overview of the modelled results of heating systems stock development between BAU and NET-ZERO scenarios across the five assessed markets.

[33] This target option is compatible with the level of net GHG reductions that would be reached in the case of a prolongation of the current policy framework (-88%). It assumes a close to decarbonised power system in 2040, with larger deployment of renewables.

[34] European Council (2024), Fit for 55, https://www.consilium.europa.eu/en/policies/fit-for-55/

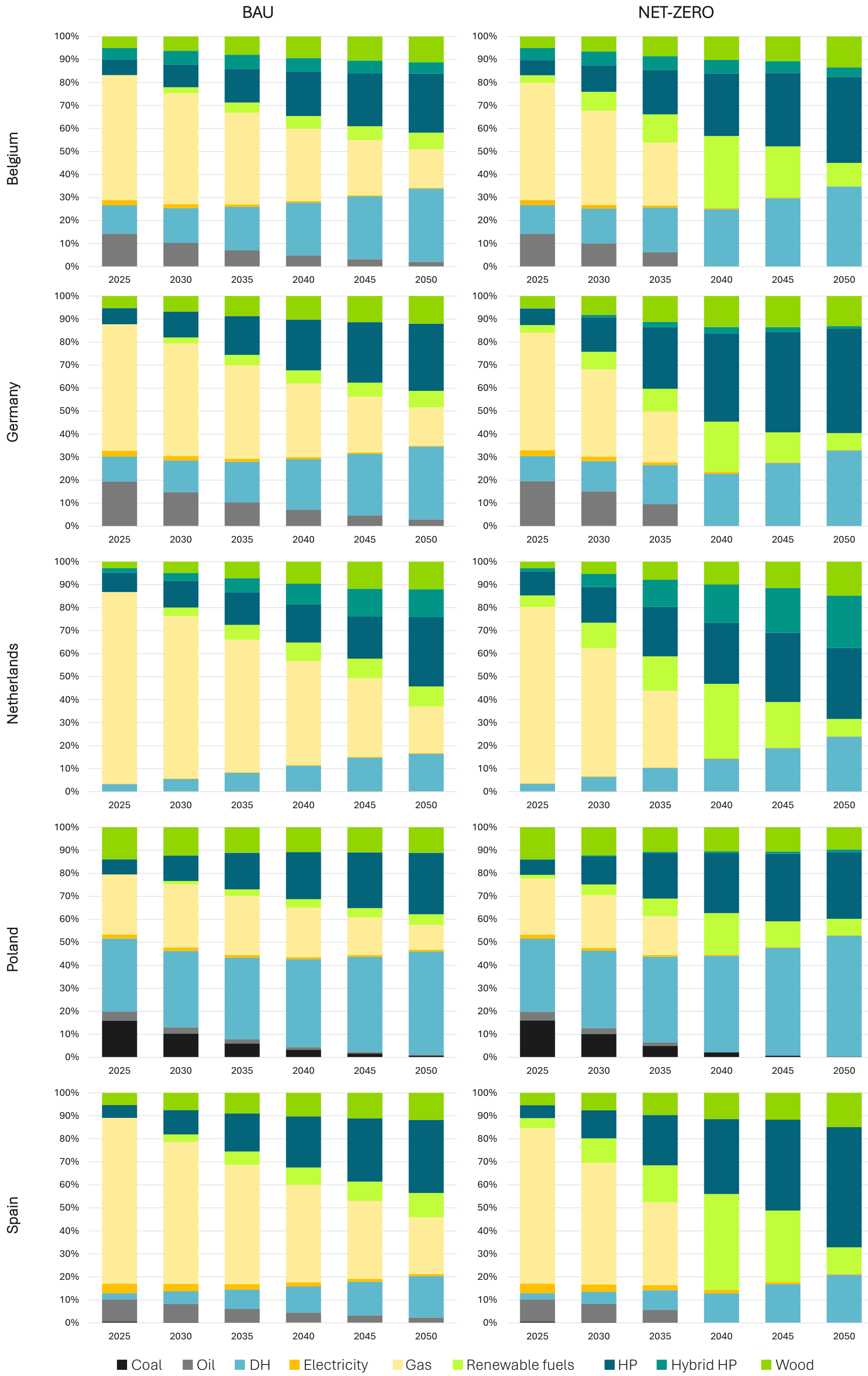


Figure 3: Heating system stock development across the five assessed markets

This shows that the currently continued reliance on fossil fuels will persist and will extend beyond 2040 for the BAU scenario. In addition to that heat pumps uptake, while noticeable, will still be below the necessary thresholds to drive the residential sector decarbonisation efforts across all five markets. On the other hand, the NET-ZERO scenario will result in a complete phase-out of fossil fuels by 2040, mainly driven by the uptake of heat pumps and the uptake of biofuels.

Final energy intensity

The main metric for quantifying the gaps across scenarios is the final energy intensity[35] (in kWh/m²a) for heating systems and domestic hot water across the five assessed markets projected from 2024 to 2050. This metric allows the estimation of the final energy consumption across the modelled scenarios and allows for gap quantification. It exclusively assesses the gaps as a result of measures performed on-site, i.e. inside or at the building, or on its plot. Putting those measures related to final energy consumption into perspective, Figure 4 illustrates the modelled pathways for the three scenarios and also includes the energy-intensity trajectory in the CRREM decarbonisation pathways (represented by the dashed line, not modelled with BEAM²) for each of the assessed markets. Box 4 highlights key differences between modelled scenarios and CRREM decarbonisation pathways.

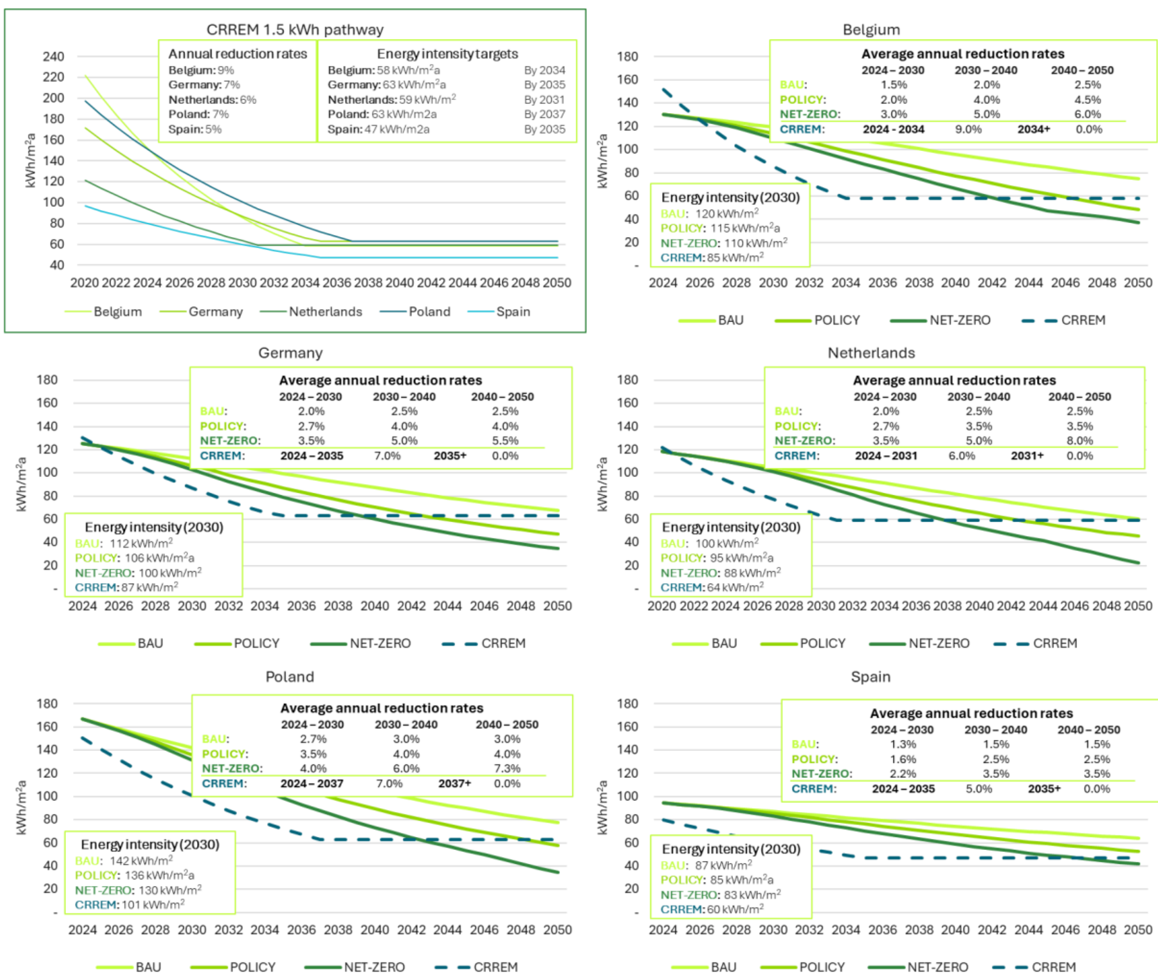


Figure 4: Final energy intensity per scenario modelled against the CRREM energy-intensity decarbonisation pathway across the five assessed markets

[35] Note: Final energy intensity here does not include ambient energy utilised by heat pumps.

Based on the assessment, considerable gaps between each of the modelled scenarios and the projected CRREM decarbonisation pathways can be identified (see Table 5).

Table 5: Final energy intensities: Quantified gaps across the modelled scenarios and comparison to the CRREM 1.5-degree pathway

<table>
<tr><th>Scenario</th><th colspan="3">Gap to other scenarios</th></tr>
<tr><td rowspan="8">BAU</td><td colspan="3">BAU to POLICY</td></tr>
<tr><td>2030</td><td>2040</td><td>2050</td></tr>
<tr><td>5%</td><td>20%</td><td>30%</td></tr>
<tr><td colspan="3">BAU to NET-ZERO</td></tr>
<tr><td>2030</td><td>2040</td><td>2050</td></tr>
<tr><td>8%</td><td>30%</td><td>55%</td></tr>
<tr><td colspan="3">Alignment with CRREM 1.5-degree pathway</td></tr>
<tr><td colspan="3">A continued BAU operation will not meet the CRREM 1.5-degree pathway and would leave significant gaps. Furthermore, BAU misses the target energy intensity cap defined by the CRREM 1.5-degree pathway even by 2050.</td></tr>
<tr><td rowspan="5">POLICY</td><td colspan="3">POLICY to NET-ZERO</td></tr>
<tr><td>2030</td><td>2040</td><td>2050</td></tr>
<tr><td>3%</td><td>15%</td><td>25%</td></tr>
<tr><td colspan="3">Alignment with CRREM 1.5-degree pathway</td></tr>
<tr><td colspan="3">The assessed current policy landscape with the existing measures in place would not be sufficient to align with the CRREM 1.5-degree pathway. In certain markets where policy measures are more mature and clearly defined, CRREM's target energy-intensity cap can be achieved by 2050 (i.e. Germany).</td></tr>
<tr><td rowspan="2">NET-ZERO</td><td colspan="3">Alignment with CRREM 1.5-degree pathway</td></tr>
<tr><td colspan="3">The target energy intensity of our NET-ZERO scenario is typically even lower than CRREM's. However, CRREM's energy intensity reduction pathways would typically require significantly higher annual renovation rates than 3%, which is what we assume to be a realistic upper limit (cf. explanation in section 2.1.1). Still, as shown in Figure 6, assuming a more rapid off-site decarbonisation (electricity grid, district heating networks and uptake of biofuels) respectively in our NET-ZERO scenario compared to CRREM 1.5-degree pathway, can lead to an almost equal decarbonisation pathway.</td></tr>
</table>

Currently, the CRREM decarbonisation pathways put emphasis on the on-site measures as a result of their methodology, which starts first by looking at the grid capacity and pace at which markets may increase renewable energy available to homes. This pressure on on-site measures is evident in the rapid energy intensity reduction rates expected in each market prior to 2030 and until CRREM's defined energy cap is met. As a result, none of the modelled scenarios could match the trajectory of the CRREM energy intensity pathway with this current focus on on-site measures. Therefore, this paper considers the technical feasibility, limitations, and impact of policies at the building-level. It proposes exploring additional measures that could enhance the effects of on-site measures without compromising technical feasibility and aims to distribute the 'decarbonisation burden' more evenly between on-site and off-site measures.

Box 4: CRREM decarbonisation pathway vs. bottom-up modelled Scenarios

The modelling used in the CRREM decarbonisation pathway follows a 'whole building' approach in which final energy consumption encompasses the total final energy delivered to the building to meet its operational final energy needs. This includes all energy consumed for heating, cooling, ventilation, lighting and powering equipment and appliances within the building. The pathway follows a top-down downscaling-framework in which it starts at the global GHG budget and emissions pathway all the way down to market-specific subsector energy- and GHG emissions intensity pathways[36].

Given the scope and focus of the paper to analyse the effects of renovations of the building stock, the modelled scenarios in this paper consider the final energy consumption for heating and domestic hot-water generation and the corresponding energy and emissions intensity projections over the years 2024 – 2050.

The scenarios are assessed with the bottom-up BEAM² model, where individual decarbonisation measures are modelled at individual building levels and scaled up to the entire residential building stock. The modelled building stock energy consumption and emissions are then calibrated with national statistics. Building stock final energy intensity and emissions intensities are then estimated by dividing the overall final energy consumption and emissions by the overall building stock floor area (see Annex 5.1 for detailed BEAM² model methodology). In this model, reduction targets and parameters are based on historical patterns, planned policies and targets, and further ambitious measures that contribute to the overall decarbonisation targets depending on the assessed scenario.

Looking at the final energy consumption distribution across residential sector in the five assessed markets, heating systems and domestic hot-water generation account for 80 – 85% of the overall consumption (except for 60% for Spain, due to lower heating requirements) and minimal shares of space cooling accounting for less than 1% of the overall consumption[37]. While not identical to the CRREM pathway composition, this still implies that a comparison with the CRREM decarbonisation pathways is possible and captures the impacts of the measures and efforts to decarbonise the residential sector. Further modelling differences between the modelled scenarios and the CRREM decarbonisation pathways include the following:

- Starting points: The CRREM energy intensity decarbonisation pathway uses the year 2020 as a base year and projects a fixed annual reduction % of energy intensity per market. The modelled scenarios start taking effect from 2024 and the effects are directly linked to the key actions on-site.
- Renovation rate and depth: For all modelled scenarios, renovation rates and depths are not fixed and exhibit a linear growth pattern per each assessed period: 2024 – 2030, 2030 – 2040, and 2040 – 2050.

[36] Institute for Real Estate Economics (IIÖ), CRREM Initiative Lead (2023), From Global Emission Budgets to Decarbonization Pathways at Property Level, CRREM-downscaling-documentation-and-assessment-methodology

[37] European Commission (2024), Energy consumption in households by type of end-use, Energy consumption in households

- Data quality and assumptions: Lack of available data and the involved level of assumptions could skew the decarbonisation pathway at the starting year if less weight is given to the worst-performing building at the current assumed renovated buildings shares.

2.3.2 Off-site

Off-site measures aim to reduce emissions within the grid or network that supplies energy for on-site uses, such as heating and domestic hot water. Thus, it generally concerns the supply of electricity, gas and district heating.

Energy supply: Grid and district heating networks

This metric explores the impact of the decarbonisation of the electricity grid and district heating networks, along with a phase-out of natural gas, which is replaced by renewable energy carriers. When considering the slow rates and depth of renovation described above, it can be viewed as the missing link to bridge the gap on the buildings level to meet decarbonisation targets. Looking at future scenario projections, the following Table 6 provides an overview of the reductions achieved for each scenario.

Table 6: Projected reductions from electricity grid and district heating network decarbonisation, and uptake of biofuels across the three scenarios and assessed markets[38]

Scenario	Metric	% Change compared to 2020 levels[39]		
		2030	2040	2050
BAU and POLICY	Electricity grid decarbonisation	30%	60%	90%
	District heating networks decarbonisation	35%	45%	70%
	Uptake of biofuels	5%	15%	30%
NET-ZERO	Electricity grid decarbonisation	35%	65%	100%
	District heating networks decarbonisation	45%	100%	100%
	Uptake of biofuels	20%	100%	100%

As depicted in Figure 5, the following key gaps can be observed on the energy supply emission decarbonisation pathways for the modelled scenarios:

[38] The results shown in Table 6 are based on an estimated adoption of the FF55/2040 climate plan. See Section 2.2.3.

[39] This refers to the relative % change compared to 2020 for each of the assessed countries. For example, a 30% electricity grid decarbonization in Poland would require a drop to around 487g CO_2e/kWh from approximately 695 gCO_2e/kWh in 2020. Whereas for Belgium would require a drop to around 116g CO_2e/kWh from approximately 166 gCO_2e/kWh in 2020.

- The BAU and POLICY scenarios currently lack sufficiently defined measures and actions to drive a fully accelerated district heating network decarbonisation, despite having clearly defined targets.
- Similarly, both scenarios lack a clearly defined framework for replacing fossil fuels, specifically natural gas, with biofuels (assuming connections to the gas grid remain). This framework is essential to eliminate dependence on fossil fuels and achieve intermediate decarbonisation goals by 2030 and complete decarbonisation by 2050.

Figure 5: Gaps in energy supply emissions decarbonisation pathways

2.3.3 Combined effect

To get a better understanding of the overall decarbonisation effects, it is important to view both sides of the coin together and assess the combined impacts of measures on-site and off-site. This is done by assessing the emission-intensity metric, measured in $kgCO_2e/m^2$, across the five assessed markets projected from 2024 to 2050. Figure 6 presents the combined impact of implementing the measures. It illustrates the emission-intensity pathways of the modelled scenarios compared to the CRREM emissions-intensity decarbonisation pathways for each assessed market.

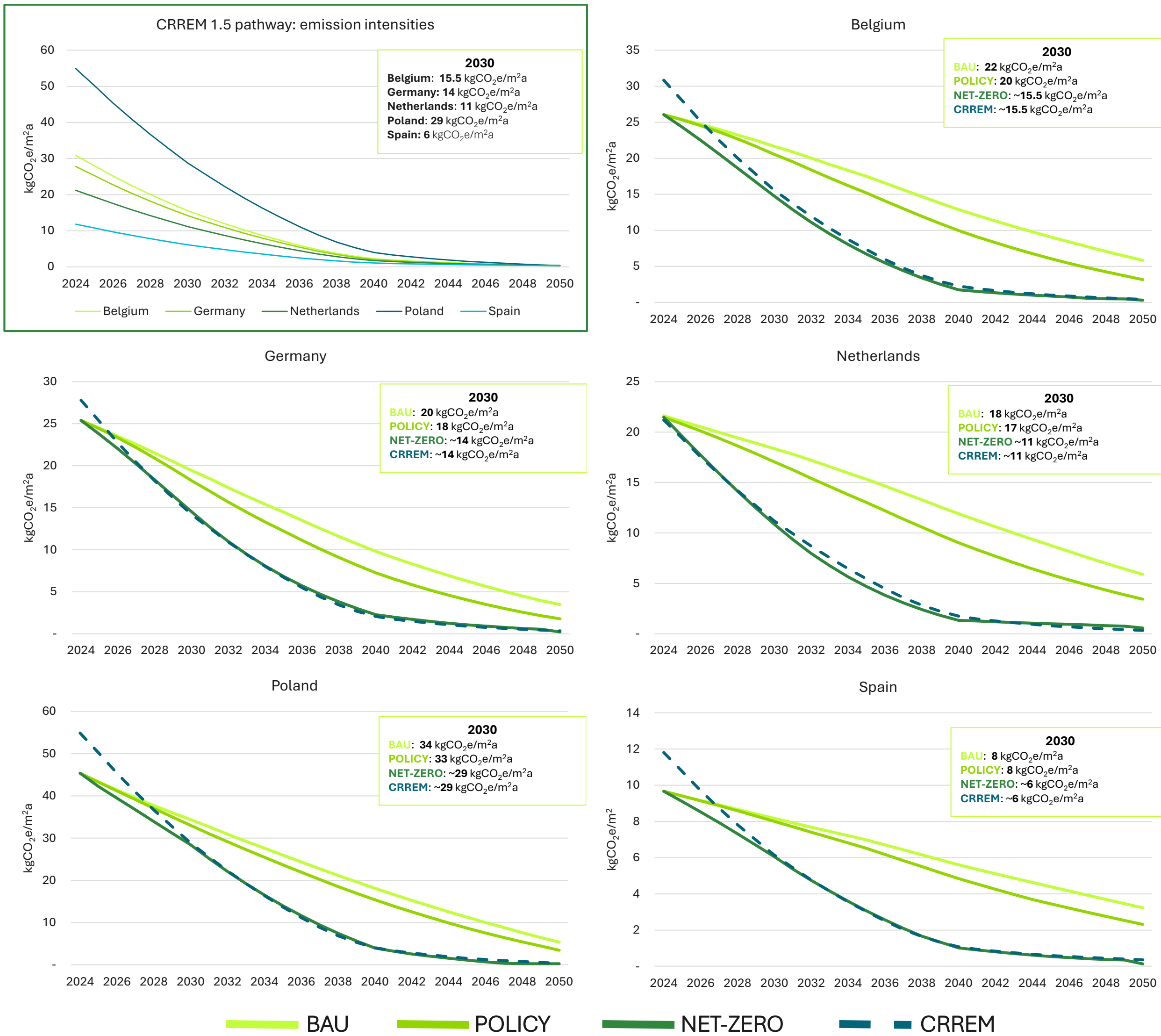


Figure 6: GHG emission intensities per scenario, modelled against the CRREM 1.5-decarbonisation pathway across the assessed markets

Also, when combining the measures, there are still significant gaps between the modelled BAU and POLICY scenarios and the projected CRREM decarbonisation pathways for each of the assessed markets. This shows that neither the current BAU scenario nor a fully compliant and enforced implementation of the POLICY scenario are sufficient to meet the decarbonisation targets and would require a significant shift in focus and significantly elevated ambition levels.

The NET-ZERO scenario acts as an alternative solution and can bridge the gaps in terms of emissions intensity and align with the CRREM decarbonisation pathway. Achieving target-level decarbonisation requires a well-balanced mix of ambitious measures both at the building level (on-site) and beyond (off-site). This connection highlights the need for coordinated action across these two areas to effectively drive decarbonization and meet net-zero targets.

3. Closing the gap: How to action implementation

The following section sheds light on how the identified gap can be bridged to achieve a decarbonised residential building sector and consequently align with the CRREM emissions-decarbonisation pathway through an alternate approach. It provides an overview of key technical measures that were identified through the science-based modelling via the BEAM[2] model. Those measures are then tied to the relevant stakeholders who can and need to take responsibility and action to implement them.

3.1 Technical measures needed to close the emissions gap

By analysing the current situation, political landscape and modelling results, it turns out that closing the identified emissions gap can only succeed by considering and ambitiously implementing each of the four groups of technical, actionable measures that exist to accelerate the decarbonisation of the building stock[40]. With a view to assigning those four measures to stakeholder groups later on, we have sorted them into two groups: on-site and off-site measures (see Table 7)

Table 7. The four groups of technical measures for building decarbonization, grouped into on-site and off-site measures

Off-site	On-site
• Measure 1: Greening the energy supply via: ○ Decarbonising the electricity grid ○ Decarbonising district heating networks ○ Uptake of biofuels and phase-out of natural gas	• Measure 2: Deeper building envelope renovations • Measure 3: Heating system upgrade and the uptake of heat pumps • Measure 4: Higher insulation standards and high-performance buildings (new buildings)

Each of the measures and sub-measures are described below, including the relevant importance of each measure to the assessed markets. As the scenarios and the measures were modelled as a whole package, the quantifiable effect of each measure separately is not provided explicitly and only the combined effects of all measures is acknowledged in this paper.

3.1.1 Off-site – Measure 1: Greening the energy supply

Greening the energy supply to residential buildings relies on three key enablers:

a. Decarbonising the electricity grid by increasing the share of renewable electricity in the overall mix

[40] These four measures in principle represent the complete set of technical actions that can be taken to decarbonise the operation of residential buildings. Improvements in control and energy management are considered part of heating system upgrades. When discussing very ambitious decarbonisation measures, such as those in the impact assessment for the EPBD 2024 proposal, this set of measures is applied, with varying rates and depths depending on the specific approach and objectives.

b. Deployment of renewable district heating networks and the decarbonisation of existing networks
c. Rapid uptake of biofuels and phase-out of natural gas and fossil heating oil

Decarbonising the electricity grid

A decarbonised electricity system is critical to maximise the benefits of electrification measures such as heat pumps and electric (heat pump) water heaters in residential buildings. The highest emissions-savings potential can be achieved where the electricity grid currently has a significant share of fossil fuels and, respectively, a high emission factor. By increasing the share of renewable electricity in the overall mix, noticeable indirect emissions (scope 2) reductions are possible, even for homes that switch to electric heating but may not be highly energy-efficient yet[41]. This sub-measure is of highest importance to markets with significant shares of fossil fuels in their electricity mix and, in particular, high emissions-intensity fuels like coal. Therefore, from the assessed markets, most benefits would be generated in Poland from this sub-measure, followed by the Netherlands and Germany. This sub-measure would be of slightly lower importance in Belgium and Spain due to their higher reliance on nuclear energy and renewables, respectively.

District heating networks

District heating networks can significantly contribute to the decarbonisation of the residential sector, largely because they can flexibly incorporate various energy sources, particularly renewables[42]. This sub-measure goes hand in hand with electricity grid decarbonisation as both rely on the integration of renewable sources in the mix. It is of particular importance in markets where district heating networks already supply a significant share of heating and domestic hot water needs, and modernisation is needed anyway. It is also considered as a major alternative to natural gas dependency, especially in dense urban areas. This is why a focus on district heating networks and their decarbonisation is of specific importance to Poland, where district heating is currently responsible for around 17% of the total heat supply[43], and the Netherlands followed by Germany and Belgium.

Rapid uptake of biofuels and phase-out of fossil fuels (gas, oil, coal)

The rapid phase-out of fossil-fuel heating systems is essential to avoid lock-in effects, i.e. continued reliance on fossil fuels, and in particular natural gas. Table 8 shows the share of fossil-fuel heating systems in 2022 in the assessed markets.

[41] While electrification and heat pumps can significantly reduce emissions, installing them in inefficient, high-energy-demand homes is not recommended. Doing so increases the burden on the electricity grid by creating higher demand peaks, which requires expensive expansion of generation, transmission, and distribution capacity. This could potentially increase heating costs rather than reduce.

[42] A district heating network may easily utilise heat from different sources simultaneously, such as (bio)gas- or biomass-driven combined heat-and power plants, large-scale solar thermal installations, and large-scale heat pumps of different types (water-water, brine-water, air-water).

[43] EU Building Stock Observatory (European Commission, 2024).

Table 8: Share of on-site fossil fuel use in space heat consumption in 2022[44]

Country	Share of gas in space heating (on-site)	Share of oil in space heating (on-site)	Solid fossil fuels (on-site)
Belgium	43.4%	37.9%	0.5%
Germany	45.1%	23.8%	0.7%
The Netherlands	79.1%	0.7%	0%
Poland	16.8%	0.9%	28.5%
Spain	25.7%	31.1%	0.4%

In markets where natural gas or fossil heating oil is the dominant mode of heating, the possibility of switching either directly or with minimal changes to biofuels like biomethane or other hydrogen blends at first sight appears to be a very attractive measure, especially for achieving significant short-term decarbonisation and thus for aligning with a CRREM pathway. On-site measures include modifying or replacing heating systems to enable the use of these energy carriers in a home. However, the actual generation of these new energy carriers - and adapting existing grids for their distribution - must happen off-site, beyond the homeowner's control. This is why we discuss it in this chapter. In the Netherlands, it is under discussion as one of the main options to achieve significant reductions in emissions in the early phase before 2030, before renovation impacts become more significant. However, biofuels are limited for use in the residential sector as sustainable volumes of those fuels are limited so far and due to competition with the need for biofuels in the industry and transport sector. As for hydrogen or hydrogen-based fuels, there is also significant uncertainty with regards to availability, the related timeline, and cost. For these reasons, most experts do not expect hydrogen-based fuels to gain significant shares in space heating until 2050, in the German market, for example.[45]

Solid fossil fuels, like brown coal or black coal, have almost disappeared as a main energy carrier for heating in most EU countries. Poland is one of the exceptions, with a still very high share in space heating of almost 30%. Being related to standalone heating systems without grid connection, this poses challenges similar to oil-fired heat generators, where heat pumps currently appear to be the most feasible replacement with a view to decarbonisation.

3.1.2 On-site – Measure 2: Deeper building envelope renovations (prioritising worst-performing buildings)

It is critical to target the worst-performing buildings for deep envelope renovations, including upgrades to insulation, windows, and air sealing. These measures aim to reduce heat losses during the colder months and therefore reduce overall energy consumption[46] and energy cost, while providing the same or even better indoor environmental for the dwellers. Furthermore, these measures significantly improve the boundary conditions for heat-pumps being run at a very high efficiency, which can mean a reduced electricity bill for heating.

[44] EU Building Stock Observatory (European Commission, 2024).

[45] For example, the project 'Die Rolle von Wasserstoff im Gebäudesektor' – after reviewing several studies on this topic – concludes with strong doubts about hydrogen ever playing a significant role in decentralised heating, and a only a minor role in district heating systems.

[46] For example, a worst-performing building with an energy consumption of over 200 kWh/m^2 can have its consumption reduced by more than 80%, down to around 40 kWh/m^2 per year, through zero-emission building deep renovation.

This approach is particularly effective across all five markets. Its importance increases in areas with older buildings (constructed before 1945 and between 1945 – 1990 for most cases) that have poor energy efficiency and an overall energy consumption higher than 200 kWh/m^{2}a, which contribute heavily to emissions. For example, this measure would have the highest impact in Poland, where buildings built pre-1945 have an average consumption of 350 kWh/m^{2}a, followed by Belgium, Germany, the Netherlands[47] and Spain[48]. By focusing on deep renovations in the least efficient buildings, the same amount of work will achieve higher savings than in better performing buildings, resulting in more rapid and effective decarbonisation.

3.1.3 On-site – Measure 3: Heating system upgrade and the uptake of heat pumps

Replacing fossil fuel-based heating systems with electric heat pumps and other electricity-based heating technologies, such as solar heating, is essential to eliminate direct emissions from residential heating. Heat pumps when paired with envelope improvements, offer a highly efficient alternative that lowers operational emissions while improving indoor comfort. Given that well-insulated buildings facilitate a high-efficient operation of heat pumps, concurrent envelope improvements (e.g. additional insulation, window upgrades) should always be implemented whenever possible.

This measure also supports resilience to future increases in energy prices by reducing dependency on fossil fuels in the short term, leading up to a complete phase out by 2040. Overall, all buildings should at least reach ‘low-temperature’ levels in order to be equipped with either heat pumps or low-temperature district heating systems. Apart from building envelope improvements, ‘low temperature’ can also be facilitated by heating system upgrades, such as optimisation of heating systems controls, and their hydronic circuits, including replacement of undersized radiators by larger ones or radiant heating systems. This measure is important across all five markets.

3.1.4 On-site – Measure 4: Higher insulation standards and uptake of zero-emission buildings (relevant for new buildings)

For new constructions, a timely shift towards a zero-emission building (ZEB) standard as required in the revised EPBD is essential. This ensures that these buildings are future-proofed and do not partially counteract the savings achieved through energy renovations or place an additional burden on energy grids. This involves setting and enforcing strict building codes, which not only include traditional elements like superior building envelopes and technical building systems, but also new ones such as low embodied carbon of the construction, and insulation, and design elements that enhance thermal performance and reduce energy consumption. By constructing buildings that are inherently energy-efficient from the outset, the need for extensive retrofitting in the future is avoided, reducing long-term costs, and contributing to net-zero targets from day one. This measure is equally important across all five markets to maximise the benefits of new building stock and avoid the negative impacts of maintaining existing construction patterns, which would require renovation later.

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[47] In the Netherlands, it is around 190-200 kWh/m^{2}a.

[48] The reason behind the Spanish building stock's lower energy-intensity factor is that most of the building stock does not require heating over longer periods and a noticeable share (>20%) is not connected to heating systems. Furthermore, five million of the worst-performing buildings are responsible for 80% of the overall energy demand for residential heating.

To get a better feeling for the importance of each measure across the five assessed markets, Figure 7 provides an indicative relative ranking for each of the actionable measures per market. A breakdown of the analysis criteria and scoring is provided in Annex 5.4.

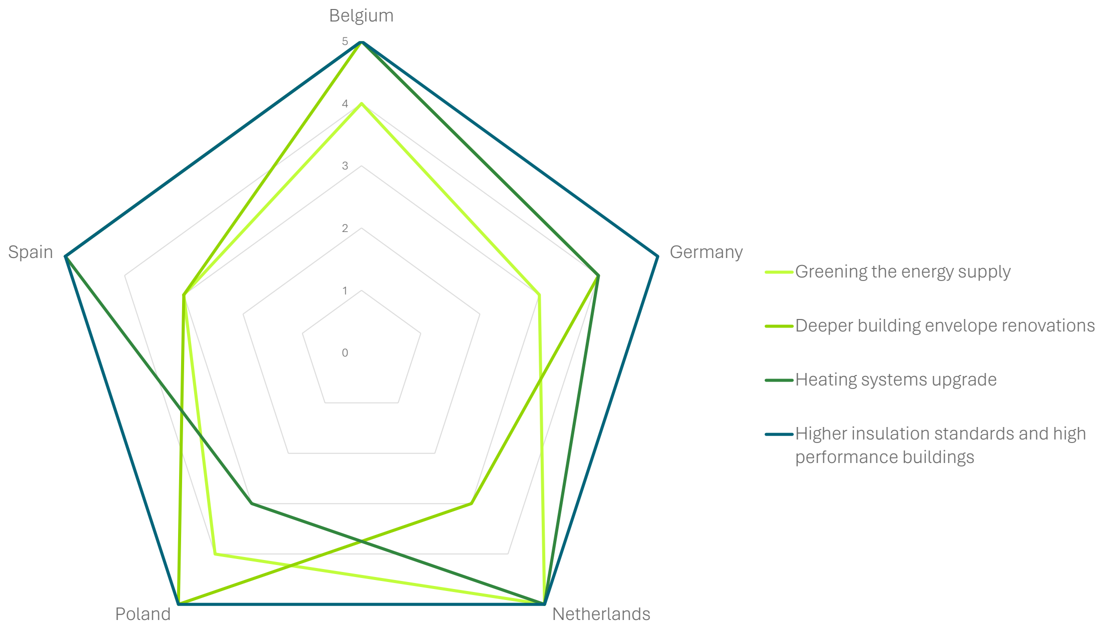

Figure 7: Relative importance of identified measures per market

While a combination of the four key measures is essential to drive decarbonisation and achieve net-zero goals, the relative importance of each measure across the five markets differs based on several factors and conditions. These differences make it essential to find individually shaped solution packages for each market, which – if they are to have a high chance of acceptance and implementation – must be developed in a well-coordinated collaborative effort by the main stakeholders. This aspect will be addressed in the following section.

3.2 Barriers for a gap-closing implementation of technical measures

Having identified the key technical measures necessary to close the emissions gap in the residential building sector, the question is why this gap exists and how it can be overcome. Factors that prevent or limit stakeholder action are typically called barriers, while factors that motivate action are called drivers. Regulatory and non-regulatory measures need to remove or mitigate barriers, and to establish or reinforce drivers. The mediocre energy performance of European buildings and their slow rate of improvement and related decarbonisation has been a persistent problem. This is why several studies exist that assess barriers causing the gap and drivers to overcome these barriers and close the gap. Ultimately, it is about what needs to change to make sufficient investments happen into above-mentioned technical measures on-site and off-site. Barriers will be addressed in this section and drivers in the next section.

Barriers for energy renovation in buildings were analysed in a comprehensive EU-wide study[49]. While the study focused on owner-occupiers' and residential landlords, installers, (larger)

[49] Hermelink, et al. (2019), Comprehensive study of building energy-renovation activities and the uptake of nearly zero-energy buildings in the EU, https://op.europa.eu/en/publication-detail/-/publication/97d6a4ca-5847-11ea-8b81-01aa75ed71a1/language-en/format-PDF/source-119528141

contractors and architects were also interviewed as they were identified as critical intermediaries, i.e. having a strong influence on their clients' decisions about energy renovations. Barriers were classified into the following categories: lack of awareness/knowledge; own and peers' attitudes/norms; personal time and effort (''transaction cost'); technical constraints; economic reasons (incl. finance), and regulatory reasons[50]. Within those, the following items turned out to be major *perceived* barriers for energy renovation of residential buildings, which means that those reasons do not necessarily objectively exist. Clear differences were identified between the ultimate decision-makers: *private owner-occupiers,* who are often related to single-family homes (SFHs), and *landlords*, who typically make decisions on multi-family homes (MFHs):

Private owner-occupiers

- **Financial restrictions**: too high upfront investment, low savings potential, too low return on investment
- **Strong dislike of loans or mortgages**: many owners only renovate when own equity is available
- **Fear of negative consequences:** dampness, mould, risk of fire, etc
- **Environmental reasons:** energy performance of building perceived to be 'OK', insulation materials are perceived to be harmful, etc
- **Regulations and perceived technical barriers:** e.g. monuments
- **Aesthetics**: strong barrier, if perceived

Landlords

- **Intransparency and uncertainty** about actual energy efficiency potential and profitability and fear of mistakes
- **Too long payback period** (specifically for insulation measures), **lack of guarantees** (quality, energy performance) from contractors
- **Too high transaction cost**: lack of staff that could sufficiently deal with complex optimisation of whole portfolio
- **Lack of motivation**: location is main determinant of property value and lease
- **Investor-user dilemma**: landlord invests and tenant reaps the savings
- **Collaboration with energy utilities is not established**: this would be needed for optimisation of portfolios
- **Aesthetics**: strong barrier, if perceived

[50] A comprehensive list of items belonging to these categories can be found in Annex 5.2.

Given the focus of this paper on financial institutions, the strong reported dislike of loans and mortgages among private owner-occupiers is noteworthy. This will be considered later when discussing the realistic role financial institutions can play in the transition.

Relative to the perceived extent of a barrier, the study revealed significant differences by age, income, and region within the EU. While the dislike of taking loans and mortgages increased with age, dealing with administrative requirements and installers was considered less of an issue with increasing age. Furthermore, rising income has made administrative requirements, perceived negative consequences of a renovation, and a lack of trust in installers less of an issue. However, regulations that only apply when a measure is actually implemented can act as a medium to a very strong barrier, depending on the country, if they are perceived to require more than the investor intends to do (see Figure 8).

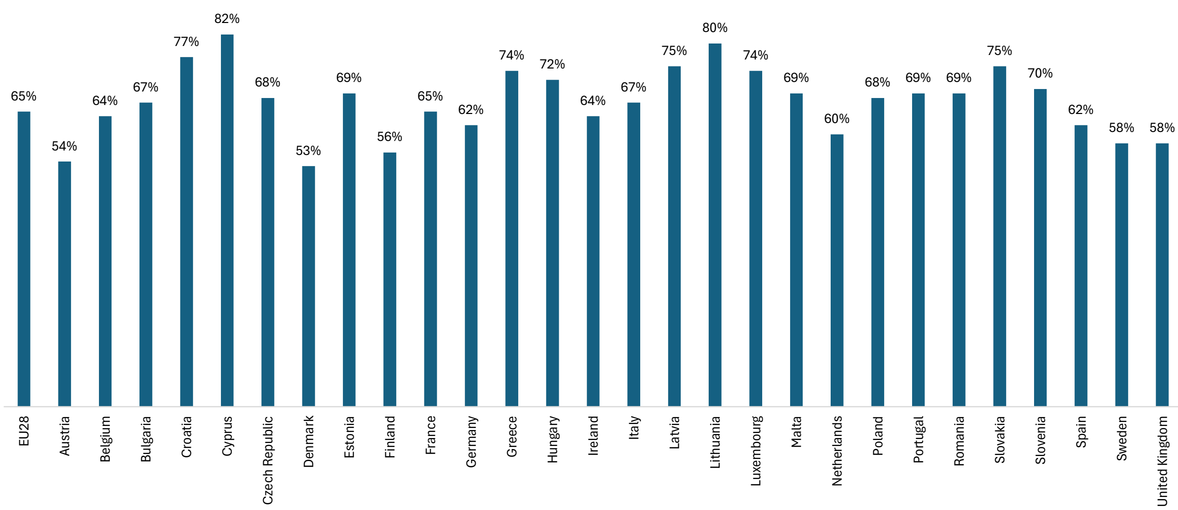

Figure 8: Share of interviewed owner-occupiers agreeing to the statement 'Regulations require more than I would naturally do'[51] by country

While the aspects presented so far are mainly related to the ultimate decision-makers, owner-occupiers and landlords, there are further barriers related to other stakeholders. Capacity shortages in the construction sector present a significant barrier to implementing both on-site and off-site decarbonisation measures. The sector faces a persistent shortage of skilled workers, particularly those specialising in energy-efficient renovations, that could create supply bottlenecks. Additionally, higher renovation rates may strain the availability of materials, equipment, and logistics. Sudden surges in demand for components such as insulation, windows, and heat pumps can lead to delays and significant price increases, as recently seen in Germany for heat pumps.

With a view to the differentiation of barriers between the four key technical measures that were previously identified, the study looked at the two on-site renovation measures (deeper building envelope renovations; heating system upgrade and the uptake of heat pumps) and did not report any differences between them. Seeing the nature of the reported barriers, this appears to be plausible. A similar set of barriers can be assumed for new buildings, while differences may exist relative to barriers for off-site measures, i.e. greening energy grids. Yet energy grids are much more regulated than on-site measures, which is why we will touch on off-site measures in

[51] European Commission (2019). Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU (p.58). Recreation of figure 35, p. 58.

the section on drivers. The main insight is that barriers to the three on-site measures vary more by who makes the final decision (owner-occupiers versus landlords) than by the type of technical measure involved.. Furthermore, differences by income, age and country show that there is no 'one-size-fits-all' approach to overcome these barriers with suitable drivers across countries and stakeholders. In this context, it makes sense that the new EPBD requires EU Member States to set up NBRPs, including a mandatory public consultation of this plan with all relevant stakeholders prior to submitting it to the European Commission. Based on this insight, a stakeholder-centric approach is also chosen for the assessment of drivers in the following section.

3.3 Stakeholder influence and roles to close the gap

Having identified the key measures necessary to close the emissions gap in the residential building sector, this section explores the pivotal role of stakeholders in driving the adoption and implementation of these measures. As explained before, the purpose of drivers is to remove barriers for needed investment decisions and to enforce existing triggers and motivations to an extent that leads to the level and type of investment which ultimately causes appropriate renovation depths and rates. Stakeholder groups such as commercial banks, governments, utilities, and media each hold varying degrees of influence and responsibility in facilitating this transition. By understanding these roles and their relative influence, this report clarifies how collaborative efforts among stakeholders in the whole construction and energy ecosystem are essential to achieving on-site and off-site building decarbonisation and aligning with CRREM emissions-intensity pathways.

The analysis starts with identifying the primary investment decision-maker[52], who holds ultimate responsibility for approving investments and plays a crucial role in implementing each on-site and off-site measure. By examining the flow of investments, the key decision-maker for each measure is identified. Subsequently, the analysis maps the stakeholders who influence these investment decisions. However, this is not done directly. Instead, it involves systematically analysing the 'decision-making context' or the 'external factors' that influence the decisions of the primary investment decision-makers. The idea behind this is as follows: if we want the 'right' measures to be implemented, the 'right' decisions must be made by the relevant decision-makers, yet those decisions are again determined by the 'right' context leading to these decisions. An instrument often used for that purpose is the PESTLE analysis (Political, Economic, Social, Technological, Legal, and Environmental). Here, it helps to identify the drivers that influence primary decision-makers in adopting decarbonisation measures. The analysis identified five key drivers[53], each aligned with one of the PESTLE pillars[54]:

1. Funding and Investment Capacity
2. Market Dynamics
3. Innovation and Technology
4. Public and Policy Advocacy
5. Regulation and Policy

[52] A primary investment decision-maker is responsible for allocating capital and making key investment decisions to implement/achieve the decarbonisation measure.

[53] A driver is a key external factor that influences progress, adoption or implementation of a specific decarbonisation measure. It shapes the environment in which decarbonisation efforts take place, either enabling or hindering their success.

[54] For the detailed mapping of PESTLE categories, derived main drivers and pivotal stakeholder groups shaping those drivers, see Annex 5.3.

Each driver is shaped by certain key stakeholder groups (see Table 9) that influence and enable these drivers[55]. For instance, national governments through regulatory mechanisms, tax incentives, and the provision of grants, are a key stakeholder group in the 'Funding and Investment capacity' driver, supporting energy-efficient building renovations. Ultimately, this results in a multitude of multi-stage interactions between different stakeholder groups, which is why in this report we will call it the '**building decarbonisation ecosystem**'. As we will discuss in Chapter 4, the degree of achieving building decarbonisation will largely depend on the efficiency and effectiveness of collaboration among relevant stakeholders. This, in turn, will depend on how well this collaboration is orchestrated.

With regards to relevant stakeholders, 12 main stakeholder groups have been identified within the context of the five key drivers that influence building decarbonisation decisions.

Table 9: Key stakeholder groups in the building decarbonisation ecosystem[56] (ordered alphabetically)

	Commercial banks		Developers
	Governments and regulators		Homeowners (institutional and individual)
	Housing associations		Installers
	Land developers and private landowners		Manufacturers
	Media		National energy system operators
	Tenants		Utilities

To identify the stakeholders with the greatest overall influence on the decision-making context for the decarbonisation of residential buildings, we assessed the drivers with the strongest impact on decision-making. This assessment then led to identifying the most influential stakeholders for shaping those main drivers. It is important to stress that great influence also comes with great responsibility for achieving a decarbonised building stock. **Unless those with great influence live up to their responsibility by deciding, acting and collaborating appropriately, net-zero pathway milestones are likely to remain out of reach**. Table 10 presents a summary of that in-depth analysis.[57]

[55] Literature review (the Annex provides detailed overview of all articles considered), ING country team inputs, SME input.

[56] For a detailed description of each stakeholder group, please compare Annex 5.3.

[57] The detailed assessment of stakeholder influence by measure is in Annex 5.5. The overview in Table 10 is meant to be indicative. In-depth stakeholder collaboration and national differences may certainly yield different weights.

Table 10. High-level overview of investment decision-makers and key stakeholders influencing that decision[58]

Investment decision-maker | Strong influence | Strong-medium influence | Medium influence

Key stakeholder	M1: Greening the energy supply	M2: Deep envelope renovation	M3: Heating system upgrade/ heat pump	M4: Higher insulation (new buildings)
Commercial banks				
Governments and regulators				
Housing associations				
Land developers and landowners				
Media				
Tenants				
Developers				
Homeowners				
Installers				
Manufacturers				
National energy system operators				
Utilities				

While this indicative high-level result may look slightly different if done country by country in a comprehensive collaborative process, we expect the main findings on the following key stakeholders to still hold:

- Due to the focus on decarbonisation of residential buildings, there is a rather **narrow set of key investment decision-makers**: Homeowners (private and commercial), developers, housing associations and utilities. Those are the stakeholders where an in-depth assessment is needed by market about what triggers, hampers, and drives

[58] For a detailed description of each stakeholder group, please see Annex 5.3. For a more detailed description of each measure, please compare section 3.1

decisions in favour of the key technical measures for the net-zero (or CRREM-aligned, respectively) decarbonisation of residential buildings.

- **Governments and regulators** are key influencers of investment decisions across all four technical measures. This is because they oversee and are responsible for all categories of policy measures, which help create, multiply or enforce triggers, mitigate or remove barriers, and create, multiply or enforce drivers.
- **Commercial banks** are another important stakeholder with considerable influence, as they finance the required transition and facilitate collaboration. Positioned at the intersection of finance and customer engagement, they play an important role, especially in supporting on-site technical measures.

The active role of governments and commercial banks in the decarbonisation of buildings is further highlighted in Chapter 4.

4. An ecosystem approach required to steer the transition

4.1 Importance of collaboration across the ecosystem

As highlighted throughout this white paper, the residential building sector is not on track to reach net zero and the gap is bound to grow, unless the momentum from the revised EPBD is effectively leveraged. Having identified the key technical measures necessary to accelerate residential building decarbonisation, the previous section also explored the influence stakeholders can potentially exert for driving the adoption and implementation of these measures and move the needle. Among the 12 identified stakeholder groups, homeowners, housing associations, developers and utilities are the ones ultimately taking the necessary investment decisions. However, governments were identified as having a strong influence on decision-making across all four main technical measures, and commercial banks particularly across on-site measures. Understanding the roles of all stakeholders, plus the decarbonisation challenge, makes it clear that achieving drastic building decarbonisation in line with CRREM emissions-intensity pathways is only possible through effective and efficient collaboration among all parties involved.

Consequently, an ecosystem approach is vital to align the goals, resources, and expertise of these stakeholders, creating synergies that overcome barriers like high costs, lack of awareness, and fragmented efforts. Collaboration ensures that every part of the system contributes effectively, enabling faster and more widespread adoption of decarbonisation measures. Each stakeholder must actively play their role, from setting policies and providing incentives to fostering awareness and delivering practical solutions.

Existing collaboration formats that aim to bring together key stakeholder groups include the Buildings and Climate Global Forum, organised by France and the United Nations Environment Programme (UNEP) in March 2024. For the first time, it provided the opportunity for ministers and high-level representatives of key organisations to initiate international cooperation, specifically for building decarbonisation.[59] At the EU level, the European Energy Efficiency Financing Coalition was launched in April 2024 to convene EU countries, financial institutions and the European Commission on energy-efficiency financing. It aligns with the objectives of the revised EPBD and thus supports Member States in the corresponding implementation, among others, through national hubs.[60]

At the national level, collaboration efforts increasingly also involve one-stop shops (OSSs), i.e. single points of contact with virtual and/or physical presence that are responsible for the entire customer renovation journey, acting as an intermediary between non-expert building owners and suppliers to ease and streamline the renovation process from beginning to end.[61,62] An OSS can be established as a public, private, or public-private entity, depending on available resources and market demands. A defining aspect of OSSs is that they bring together all renovation-related players, thereby connecting the fragmented renovation market and

[59] https://www.unep.org/events/conference/buildings-and-climate-global-forum

[60] https://energy.ec.europa.eu/topics/energy-efficiency/financing/european-energy-efficiency-financing-coalition_en

[61] Boza-Kiss, B. et al. (2021), One-stop shops for residential building energy renovation in the EU, One-stop shops for residential building energy renovation in the EU

[62] Boza-Kiss, B. & Bertoldi, P. (2018), One-stop-shops for energy renovations of buildings, One-stop-shops for energy renovations of buildings

simplifying the renovation process.[61,63] Over the past 10 years, more than 60 OSSs have been developed across many European markets. Prominent OSS examples include Reimarkt (NL), Ile-de-France Energies (FR), HomeGrade and RenoWatt (BE), Opengela (ES), and the ProRetro research project (DE).[61,62] According to Boza-Kiss et al. (2021), EU-based OSSs currently account for about 100,000 renovation projects per year, and have the potential to cover 5-6% of the renovation volume of 35 million buildings in 2030[62]. OSSs as an ecosystem approach must be incorporated within existing regulation to be an impactful tool to propel EU building decarbonisation. This is why the revised EPBD requires Member States to establish OSSs (Article 18), and the Energy Efficiency Directive (EED) encourages the use of OSSs as an information- and awareness-raising tool (Article 22).

Within such an ecosystem approach, it is crucial that governments act as enablers to set favourable framework conditions to drive the transition where subsequently, all key stakeholders need to take on their role. At the same time, commercial banks play an important part as facilitators and connectors by financing the transition and leveraging their networks to communicate opportunities and incentivise actions through trusted partners. The importance of action for these two stakeholder groups is elaborated on below.

4.2 Opportunity for governments to take on their responsibility

The in-depth analysis on the roles of different stakeholders identified governments as key ‘influencers’ in decisions about residential building decarbonisation. Governments control the full range of policy instruments, and orchestrate which stakeholders are addressed (obliged, enabled) by these instruments. This can be briefly summarised as follows:

- **Regulate**: This is about setting obligatory legal requirements, both on-site and off-site, such as building codes, decarbonisaton targets, emission trading systems and emission caps, shares of renewable energies or solar roof obligations, MEPS, or bans of fossil fuels and fossil-fuel heating systems. It is the most powerful tool policymakers have and may lead to unpopular decisions. Therefore, the next two categories are usually preferred whenever feasible and as long as they are effective.
- **Promote**: This category may include instruments to promote on-site and off-site measures. Typically, economic instruments are discussed, such as grants, preferential loans, tax incentives, and incentivising energy tariffs. Depending on where the financing of these measures comes from, e.g., levies or taxes, different parts of the population may be affected.
- **Inform**: Information and capacity building include awareness campaigns for various stakeholders on financial incentives, as well as curriculum updates for installers, students, etc.

Current policy instruments, especially regulatory instruments such as energy performance certificates or minimum energy performance requirements for new buildings, largely result from national transposition of requirements set out in the EPBD. The first edition of the EPBD went into force in 2002, with major revisions in 2010 and 2018. Today’s regulations in EU Member States on the energy performance of buildings mainly stem from implementing those different EPBD editions. However, a **major revision of the EPBD** entered into force in May 2024. The revision’s new requirements have not yet been implemented in any of the Member States. This is noteworthy because, unlike previous editions, the 2024 revision explicitly states for the first

[63] Turnkey Retrofit (2021), Underpinning the role of One-Stop Shops in the EU Renovation Wave, [Underpinning the role of One-Stop Shops in the EU Renovation Wave]

time the goal of ‘achieving a zero-emission building stock by 2050’. The main objectives of the revised EPBD with a view to technical measures for achieving this target were already communicated in the European Commission’s Renovation Wave communication:

- at least double current renovation rates of public and private buildings by 2030
- foster deep renovations.

These technical measures are in line with the conclusion from the scenarios for a zero-emission building stock that have been performed as part of this paper.

All those aspirations are underpinned by several new or upgraded provisions, such as:

- ‘**National Building Renovation Plans**’ **(NBRPs)**: a significantly enhanced successor of previous ‘Long-term renovation strategies’
- **Trajectories for progressive renovation of residential buildings**: i.e., a steady decrease of the average primary energy consumption of the residential building stock in line with a pathway leading to zero-emission by 2050. At least 55% of the decrease in average primary energy consumption must come from the worst-performing buildings.
- A new standard for new buildings, called ‘**ZEB’**
- Mandatory deployment of active **solar energy** systems **in buildings**
- Improved **Energy Performance Certificates (EPC)**
- A **definition of deep renovation, i.e., a renovation to nearly zero-emission building before 2030, and to zero-emission building from 1 January 2030 on,** and the introduction of building renovation passports
- **New provisions on financial incentives** for energy renovations plus a comprehensive **portfolio framework for voluntary use by financial institutions** by 29 May 2025.
- Mandatory implementation of **OSSs**, ‘*targeting all actors involved in building renovations, inter alia, homeowners and administrative, financial and economic actors, such as SMEs, including microenterprises.*’[64]

The new requirements mean a step-change in the effort the EPBD demands from EU Member States in decarbonising the building stock and involving other relevant stakeholders. NBRPs are now meant to be concrete renovation plans, while their predecessor, ‘Long-Term Renovation Strategy’ (LTRS), were sometimes seen as abstract strategies.[65] Several new, highly specific requirements now compel Member States not only to develop plans using a standardised template but also to monitor progress.

Member States have to deliver a first draft NBRP to the European Commission by 31 December 2025. ‘To support the development of its NBRP, each Member State shall carry out a public consultation on its draft NBRP prior to submitting it to the Commission.’ Within six months after submission, the European Commission will assess the draft plans. If appropriate, the Commission is to issue tailored recommendations, which Member States must take into account for their final NBRP to be submitted by 31 December 2026.

In a nutshell, **2025 provides an outstanding opportunity for EU Member States to take on the responsibility clearly put on them by the EPBD** – by setting up draft NBRP in line with a zero-emission building stock by 2050, and by setting the course towards a proper transposition

[64] EPBD 2024, Art. 18

[65] Hermelink et. al (2024) - The EU Energy Performance of Buildings Directive - Key Regulation for a Carbon-Neutral Building Stock by 2050

of the EPBD until May 2026. Yet **2025 is also the crucial time to act for all other stakeholders, including commercial banks**, to engage themselves and mobilise other relevant stakeholders to collaborate in a national effort on zero-emission-compliant NBRPs.

4.3 Commercial banks' active role in enabling the transition

As highlighted in this paper, commercial banks, positioned at the intersection of finance and customer engagement, are well placed to play an active role in financing the required transition and facilitating stakeholder collaboration. In particular, they should strongly pursue but not limit themselves to the following action items to make an important contribution to accelerating residential building decarbonisation.

Making renovation more affordable: Commercial banks should explore innovative mechanisms and products to make renovations more attractive to customers, particularly by assessing the impact of pricing and incentives on strengthening the business case. For instance, Triodos Bank introduced a sliding scale of interest rate discount based on the energy label of the house with their first green mortgage in 2012. Thus, the higher the energy efficiency level of the building, the lower the interest rate for the customer.[66]

Commercial financing can be further amplified through collaboration with EU and national governments to develop public-private blended finance instruments, leveraging shared resources to reduce financial barriers for homeowners. A potential financing mechanism to delay deep renovation costs for homeowners could concern a proposed EU Renovation Loan, i.e. a privately contracted loan without cash interest backed by an EU guarantee. It would accrue at EU-borrowing costs upon the earlier of transfer, sale or its 30-year maturity, thus leading to direct cash savings together with additional deep renovation benefits for homeowners.[67] Such measures might also help overcome the strong dislike of many private homeowners against loans and mortgages, as pointed out in Section 3.2.

Making it easier to renovate: Homeowners should find the information and materials required to educate themselves and take decisions on renovations in a quick and simple manner, including potential technical measures, related costs, funding options, estimated rate of returns and benefits. This is where commercial banks should support homeowners to facilitate the information and decision process on deep renovations. Commercial banks started to build corresponding platforms and formats, e.g. ING launched the ING Upgrader in December 2024. It's a five-step service for their customers to facilitate the renovation of their homes, from energy saving and financing advice towards installation of the selected sustainability measures.[68]

To facilitate the customer journey and convergence rates, commercial banks should continue to develop and improve renovation platforms and assistance services, aiming in particular to integrate all materials and services in one place (e.g. through OSSs). This could also be combined and integrated into ecosystem platforms to improve the services jointly with all key stakeholders to simplify the homeowner renovation journey as much as possible.

Collaborating with stakeholders and leveraging of networks: Commercial banks can connect diverse stakeholders and foster collaboration critical for building decarbonisation. By

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[66] https://www.triodos.com/en/as-one-to-zero

[67] Climate Strategy & Partners (2022), The EU Renovation Loan, A new instrument to fund the EU Renovation Wave, https://www.climatestrategy.es/press/ERLReport03112022.pdf

[68] https://www.ing.com/MediaEditPage/ING-introduces-ING-Upgrader-for-sustainable-and-future-proof-living.htm

engaging with governments, technology providers, building owners, and other key players, they can create synergies by unifying expertise that accelerate the adoption of sustainable solutions. Their influence extends beyond financing, as they can facilitate knowledge exchange, and align incentives to support an ecosystem approach. Consequently, commercial banks can act as catalysts, bridging gaps between stakeholders and being a part of driving coordinated efforts to decarbonise building portfolios.

An example of how commercial banks can leverage their collaboration potential is the Swiss cantonal bank Basellandschaftliche Kantonalbank (BLKB), through its ‘home2050’ digital platform. Developed in collaboration with two regional energy suppliers, this platform streamlines the process of adopting energy-efficient measures, such as installing photovoltaic systems, replacing heating systems, and setting up electric vehicle charging stations. Property owners benefit from expert-led on-site inspections, a curated comparison of offers from trusted installation partners, and tailored financing solutions provided by BLKB. By coordinating expertise, services, and financing, BLKB exemplifies how commercial banks can collaborate with stakeholders to create a cohesive ecosystem for advancing building decarbonisation.[69]

The above-mentioned action items and examples underscore the active role that commercial banks can play in residential building decarbonisation. However, these efforts have only involved a limited number of stakeholders so far, while consolidated action is needed.

4.4 Strong centralised platforms are needed to accelerate residential building decarbonisation

This white paper emphasises the need for a multi-stakeholder approach to achieve residential building decarbonisation, i.e. collaboration of all key stakeholder groups (commercial banks, governments and regulators, developers, homeowners, housing associations, installers, land developers and private landowners, manufacturers, media, national energy system operators, tenants as well as utilities) who take decisions about decarbonisation measures and/or have the power to create a favourable environment to make those decisions happen. As EU Member States create their NBRPs, it is critical that all these stakeholders are involved and actively contribute to the plans, and to make them embrace and jointly follow up on and implement those plans. Collaboration is essential to drive a large-scale renovation wave, targeting both on-site and off-site decarbonisation measures. Institutions need to unite to define a shared path forward, which could include issuing a joint commitment or statement to accelerate progress and ensure the ambitious net-zero goals are met. In this scope, commercial banks should leverage their interconnectedness to advocate for the necessary actions, proactively connect key stakeholders, and collaborate on creating an aligned, accelerated pathway to net zero, while influencing residential building decarbonisation.

Establishing or reinforcing[70] **centralised platforms for coordinating residential building decarbonisation** could be a potential format to foster collaboration, innovation and actionable progress. Currently, mostly decentralised formats exist where only parts of the stakeholders are represented. Stronger centralised platforms would unite key stakeholders from the built environment through roundtables and working groups with the key aim of jointly defining and advancing action. Such a platform could include or further strengthen the following components:

[69] Home2050 (2024), A Holistic Solution for Your Property.

[70] At national level where bodies partially exist.

- **Knowledge exchange, roundtables and working groups**: The platform should foster knowledge exchanges and host regular roundtables to unite the defined key stakeholders in the built environment. These forums would facilitate the definition of required actions and corresponding plans and responsibilities together with sharing of insights, best practices, and innovative solutions to accelerate residential building decarbonisation. Working groups could be set up for each of the key technical decarbonisation measures defined, including all respective stakeholder groups.
- **Exploring OSS**: Additionally, the platform could explore the establishment of an OSS model, drawing inspiration from existing OSS initiatives. By acting as a single point of contact for homeowners, the OSS would streamline the renovation journey with tailored services, from energy audits and financial guidance to coordinating suppliers and post-renovation monitoring, ultimately making decarbonisation more accessible and effective.
- **Joint data gathering**: The collection of energy usage data would further strengthen the platform, potentially allowing stakeholders to aggregate anonymised energy usage and retrofit performance data. Such insights can identify trends and provide input to measure progress towards shared decarbonisation goals.
- **Collaborations with experts**: Best practices on and build partnerships with energy advisors, SMEs, and construction professionals could be shared to establish a support system for energy-efficient renovations.
- **Financial and non-financial products**: The platform could also support exchange on private financing instruments, such as Property-Linked Finance, Green Mortgages and Sustainability-linked Loans and Bonds[71]. In addition, information and guidance could be provided on options of public financing and subsidies and discussions could be sparked on innovative mechanisms, e.g. involving public/private/blended financing options. This could be explored in the scope of the National Hubs of the European Energy Efficiency Financing Coalition.

A key objective of such a new platform for residential building decarbonisation would be to jointly define a shared path forward such as issuing a **joint commitment** or statement to accelerate progress and ensure advancement towards net zero. This would ideally be enshrined in and aligned with the NBRPs. The commitment should highlight the need for all key stakeholders to jointly act together as the corresponding responsibilities and actions are closely interlinked. To use the momentum, involvement of senior level sponsors would be a prerequisite to ensure political buy-in. Such a centralised ecosystem platform would serve as a cornerstone to drive collective progress, enabling commercial banks to play an active role in bringing together diverse stakeholders to unify efforts, foster innovation, and define a shared, actionable pathway towards accelerating residential building decarbonisation.

[71] PCAF (2024) 'Enabling Building Decarbonization Through Sustainable Finance'. Retrieved from carbonaccountingfinancials.com

5. Annex

5.1 Overview of the Built Environment Analysis Model (BEAM²)

The Built Environment Analysis Model (BEAM²) is a detailed bottom-up building stock assessment model. It is set up within the framework of the European Performance of Buildings Directive EPBD and the general terms and definitions are aligned with it. The calculation methodology follows the framework set out in the Annex to the EPBD and EN ISO 52016. As all calculations are executed for a highly disaggregated building stock with all its characteristics, the following description of the methodology and calculation process applies for all sub-segments of the building sector within the model.

The following Figure 9 provides an overview on a simplified tailored structure of the BEAM² model for the context of this white paper.

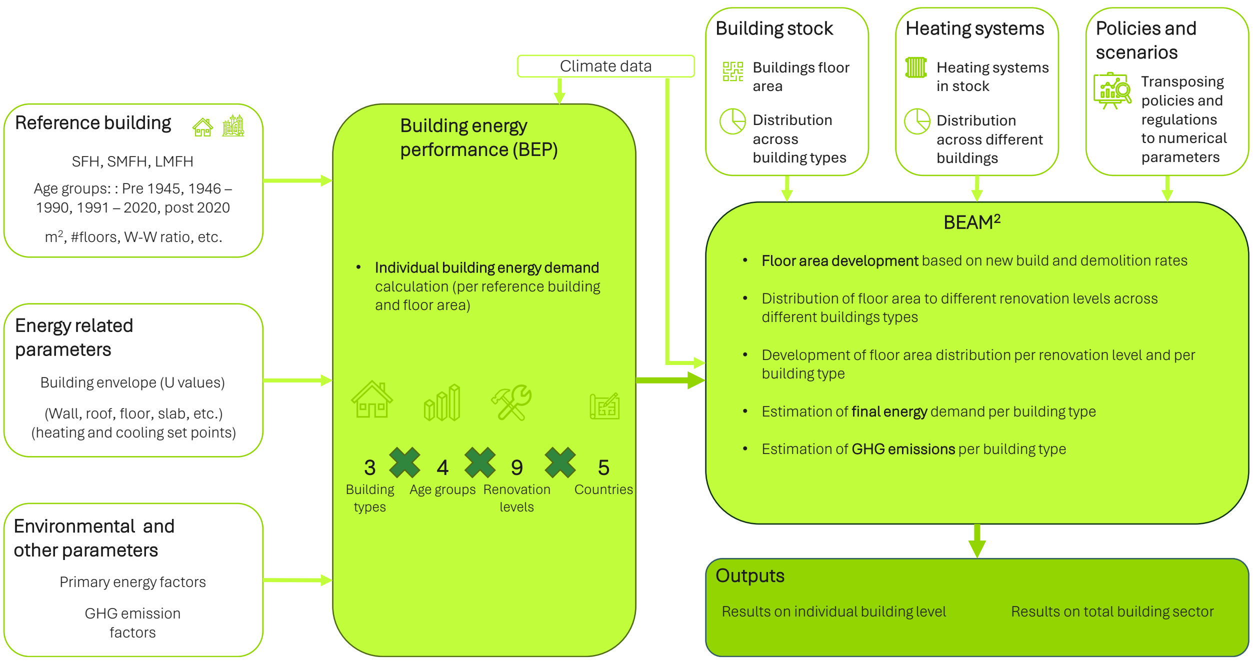

Figure 9: General overview of the BEAM² model structure

Basic input to the model is data on the building stock such as building types, floor area, age groups, retrofit levels, heating, ventilation and air-conditioning (HVAC) systems in stock and population. Furthermore, the climate data such as temperature and irradiation are required. Based on this data, a status-quo inventory of the building stock can be constructed.

For the scenario analysis as central part of the model, additional input data with respect to population forecast, GDP development, new building, demolition and retrofit activities, thermal insulation standards, heating, ventilation and air-conditioning equipment, renewable energy systems and energy-efficiency measures is required. With respect to the overall energy performance, the GHG-emissions factors and primary energy factors are required per fuel type, and GHG emissions for energy efficiency and HVAC systems.

The calculation process over the scenario timeframe is organised as follows: based on the initial floor area distribution along the reference buildings (RB), age groups (AG), retrofit levels (RL), heating systems (HS), domestic hot-water systems (DHW) and cooling systems (CS), a forecast for the floor area is done considering new building, demolition and retrofit programs for all or parts of these combinations. All activities in year i have an effect starting in year i+1.

The main outputs of the model are the floor area developments for RB, AG, RL, HS, DHW and CS. The next step is calculating the useful energy demands for space heating and DHW. From this, the final energy demand for heating and DHW is derived. For the overall energy performance, the GHG emissions and the final energy demand are calculated.

5.2 Individual market building stock, input parameters, and policy assessment

The following sub-sections provide an overview on the input parameters per market and the data sources used for post processing and preparation for the BEAM[2] model. This includes a breakdown of:

- Residential sector share of final energy demand by type of end-use;
- Building stock and useful area distribution across the residential buildings per building type and age group;
- Current state of renovation per building type and age group; and
- Heating systems distribution per building type and age group.

In addition, the section provides an overview of the policy assessment and scenario parameter definitions for each market. It delves into market-specific policies for the decarbonisation of the buildings sector, particularly the residential sector, and includes the classification of measures and implemented measures for scenario definitions.

Policies and regulations are one of the key drivers for decarbonisation, along with the several mechanisms like information campaigns, labelling, voluntary agreements, financial and fiscal measures, and other technical measures. At the EU level, and across the five assessed markets, several measures aimed at decarbonising the building sector are mainly introduced as part of each member state's long-term renovation strategy. Figure 10 provides the share of the type of measures present in each member state, targeting the building sector.

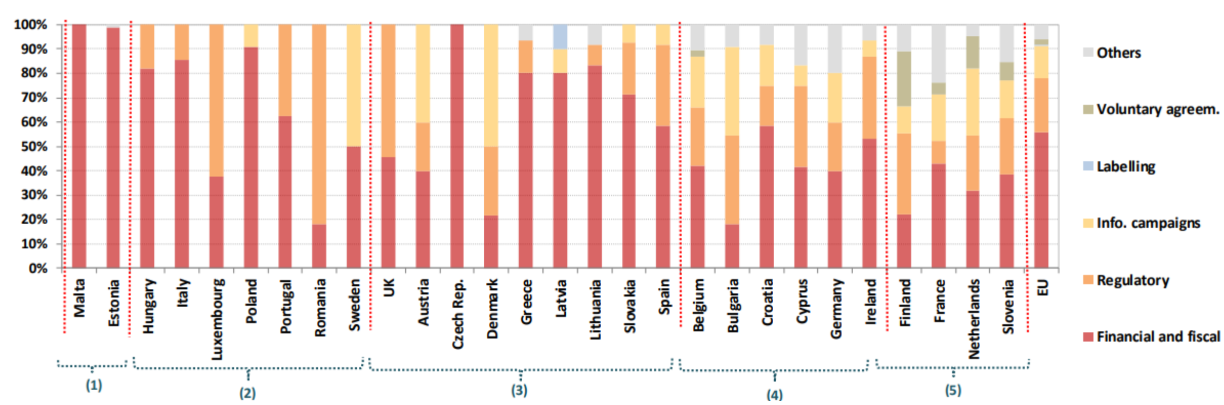

Figure 10: Type of measures for the building sector implemented in each member state

5.2.1 Belgium

Final energy consumption breakdown by type of end-use across the residential sector

In Belgium, heating and DHW needs constitute the largest share of the total residential sector energy consumption with around 86%, which underscores their importance in further decarbonisation efforts. Figure 11 provides an overview of the final energy consumption by type of end-use in Belgium.

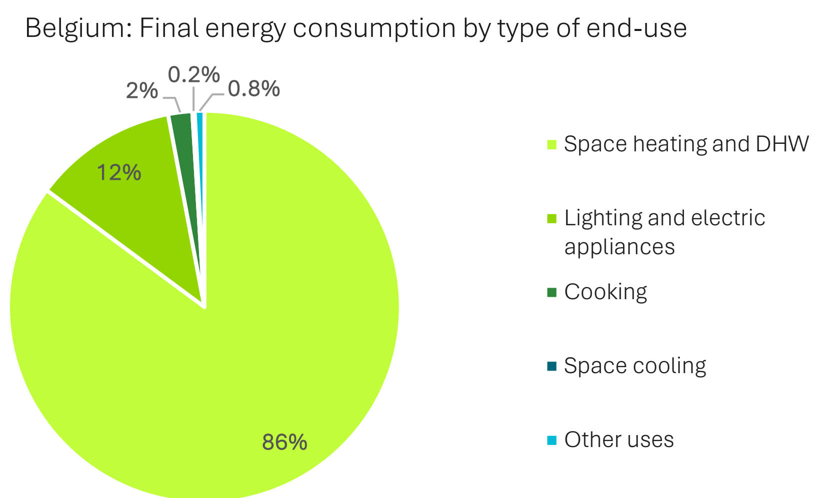

Figure 11: Share of final energy consumption by type of end-use – Belgium
Adapted from: EUROSTAT – Energy consumption in households 2022[72]

Useful floor-area distribution

Belgium has a total of about 600 Mm² of useful floor area across its residential building stock, with the majority (66%) being SFHs[73]. Figure 12 provides an overview of the useful floor area distribution per residential building type in Belgium.

The rate of new building construction in Belgium is relatively low, averaging just 0.8%[74] per year, indicating limited expansion in housing stock. Similarly, the demolition rate is also quite modest at 0.08% per year on average[75]. The current construction rate is quite low and is reflected in the significant housing shortage in Belgium, with demand far outpacing available supply[76].

[72] European Commission (2024), Energy consumption in households by type of end-use, Energy consumption in households

[73] EU Building Stock Observatory

[74] Based on the average construction rate over the past 10 years: Statbel, the Belgian statistical office

[75] Based on the average demolition rate over the past 10 years: Statbel, the Belgian statistical office

[76] The Brussels Times

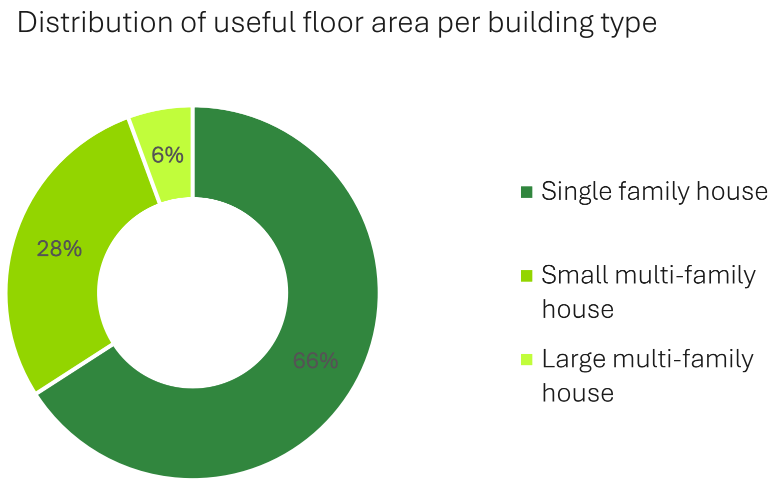

Figure 12: Distribution of the floor area in the residential sector in Belgium
Adapted from EU Building Stock Observatory database[77]

A significant portion of the total floor area in Belgium, estimated at around 46%, has a lifetime below 40 years, and was constructed after 1990. In contrast, older buildings built prior to 1945 account for around 27% of the total floor area. Figure 13 shows the distribution of building types by age group in Belgium.

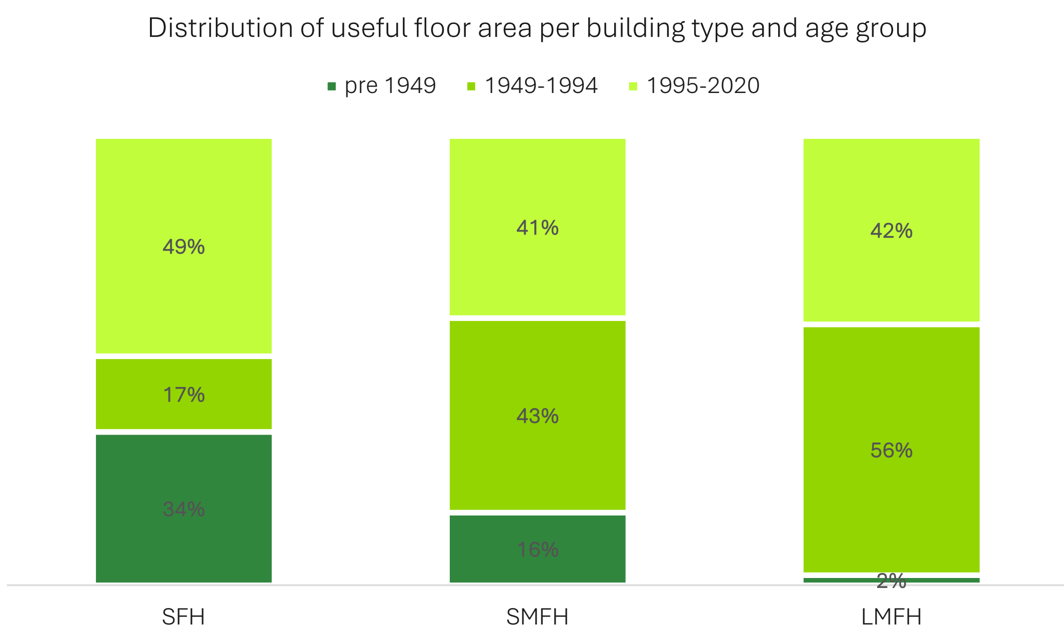

Figure 13: Distribution of building types per age group in Belgium
Adapted from EU Building Stock Observatory database[78]

[77] EU Building Stock Observatory
[78] EU Building Stock Observatory

Current state of renovation

Figure 14 shows the distribution of buildings by renovation status in Belgium. The data, drawn from the EPBD-IA[79] study for the EU Western Zone, provides a detailed look at the renovation status of residential buildings by type and age, highlighting the concentration of renovation efforts and identifying trends across different building types.

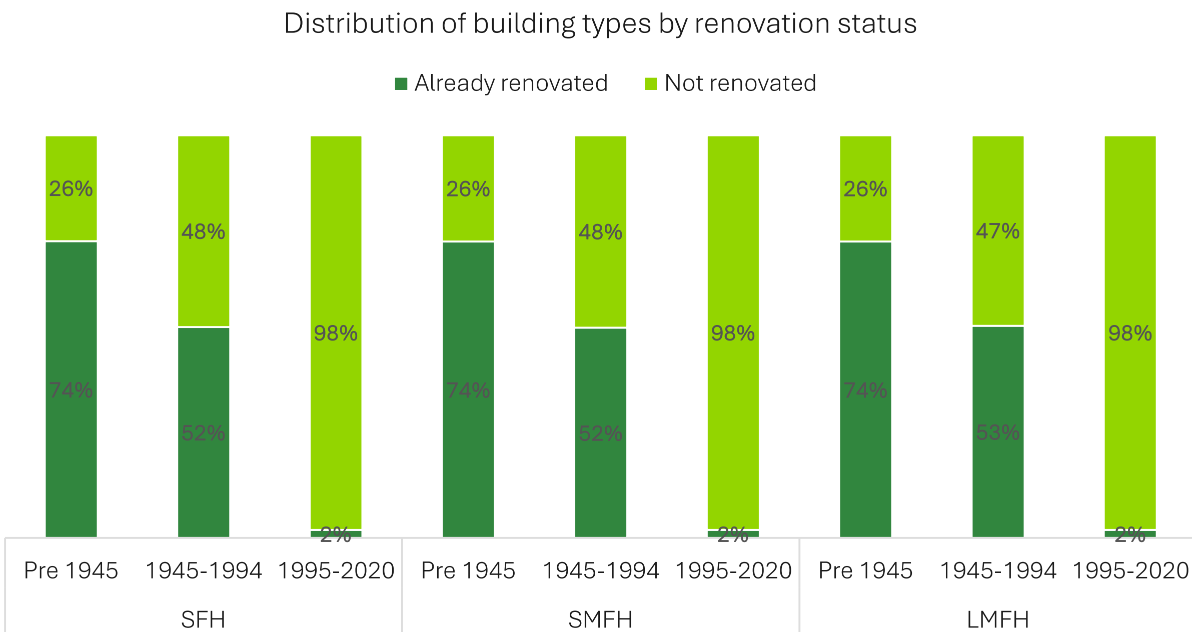

Figure 14: Distribution of buildings by renovation status in Belgium

Heating systems distribution

The distribution of heating systems per building type and age group in Belgium is presented in Figure 15. The analysis of heating systems in Belgium reveals a significant dependency on gas-based systems across all building types and age groups, while oil-based systems continue to hold a considerable share, especially in older buildings. In SFHs built before 1945, gas heating dominates at 53%, followed by oil-based systems at 37%. This reliance on fossil fuels persists in post-1945 SFH, though with a modest shift towards gas (increasing to 60%) and a slight rise in renewable options such as heat pumps (heat pump and hybrid heat-pump systems at 7%). In more recent SFH, gas remains prevalent at 55%, but the adoption of heat pumps has grown significantly to 24%, indicating a slow but positive trend toward decarbonisation[80].

A similar pattern is evident in multi-family buildings, where SMFHs and LMFHs built before 1945 show a high gas dependency (both at 63%), with oil following at around 22%. District heating plays a secondary role in SMFH, accounting for 11% pre-1945 and rising to 19% in buildings constructed between 1945 and 1994, with a further increase to 26% in the 1995-2020 cohort. In these newer buildings, direct electricity and heat pumps also make inroads, suggesting a

[79] Technical assistance for policy development and implementation on buildings policy and renovation - support for the ex-ante impact assessment and revision of Directive 2010/31/EU on energy performance of buildings.

[80] Technical assistance for policy development and implementation on buildings policy and renovation - support for the ex-ante impact assessment and revision of Directive 2010/31/EU on energy performance of buildings.

gradual diversification of energy sources. LMFHs reflect a similar trend, though biomass heating systems also become a notable addition in the latest age group.

The pervasive reliance on gas and oil-based systems underscores the scale of interventions required to achieve a low-carbon building sector in Belgium. This dependency, particularly in aging building stock, suggests that significant retrofitting and incentives for renewable heating systems will be essential to accelerate the transition. The modest uptake of district heating and heat pumps, although encouraging, remains insufficient to meet decarbonisation targets and indicates a need for heightened policy focus, especially in urban and multi-family residential contexts.

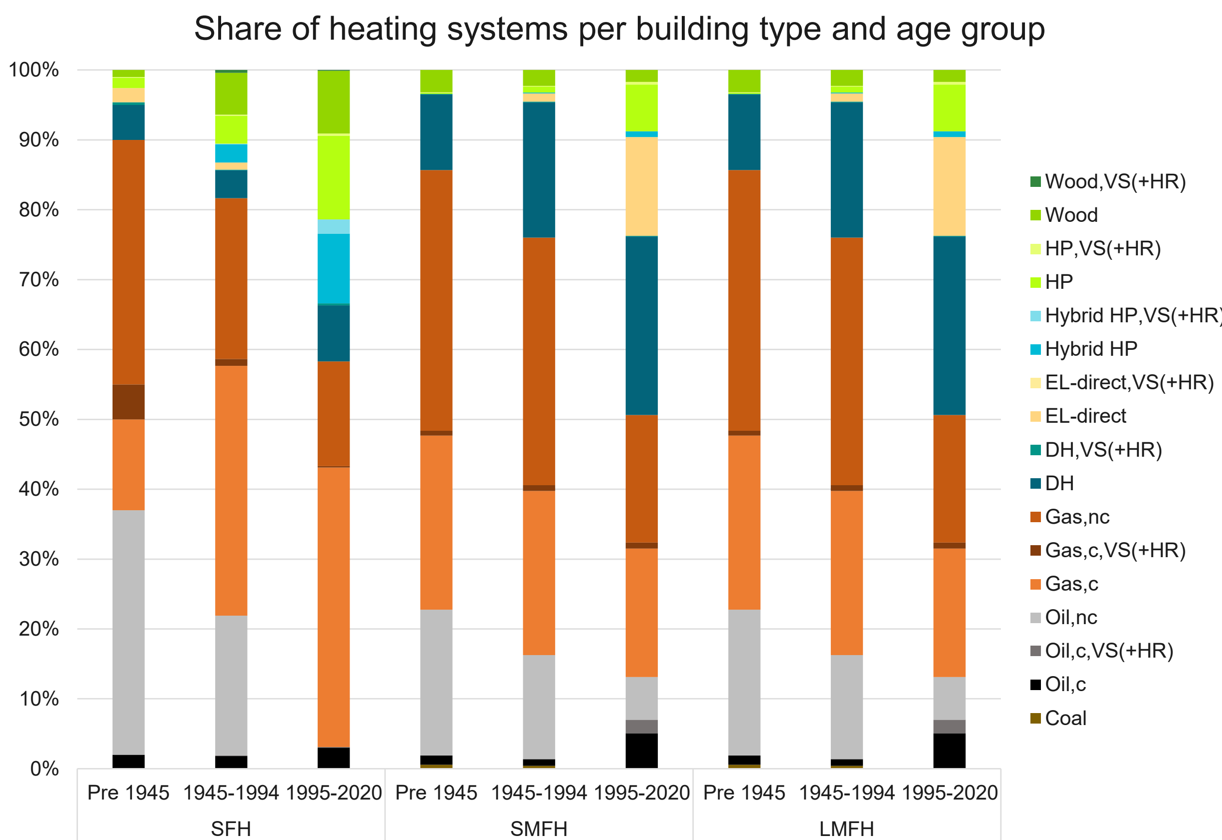

Figure 15: Share of heating systems per building type and age group in Belgium
Adapted from EPBD-Impact Assessment Study and European Heating Industry

Building stock energy performance

Building stock energy performance and final energy consumption is influenced by several factors namely, building characteristics (age, insulation quality, size, construction material), energy systems and appliances, user behavior, climate and weather, energy efficiency measures and other external factors. Overall, the building stock in Belgium is characterised by relatively high final energy consumption with buildings built pre-1945 having a final energy demand on average of more than 350 kWh/m^{2}a. The high energy consumption is observed towards the 1980s with average final energy demand of around 250 kWh/m^2a before it starts dropping to an average of 150 kWh/m^2a from the 1990s onwards[81].

From the perspective of this paper, buildings with a final energy consumption of 200 kWh/m^2a and above are considered worst-performing. Based on this criterion, buildings constructed before the 1990s in Belgium can be seen as the worst-performing buildings and in need of energy renovations.

The distribution of buildings along the EPC categories in Belgium varies slightly within regions; Brussels (on average) 0.5% of homes are class A or above, 4% are class B, 8% are class C, and over 85% are class D and lower[82]. In Flanders, 2% of homes are class A or above, 22% are class B, 23% are class C, and over 50% are class D and below. In Wallonia, 1% of homes are class A or above, 9% are class B, 14% are class C, and over 75% are class D and below[83].

Policies and measures

The Federal Climate Law is considered the key climate legislation and acts as a framework that governs Belgium's overall climate strategy, ensuring coordination among federal and regional governments. It aims to align with the EU Green Deal and sets general guidelines for achieving carbon neutrality by 2050, with an interim goal of reducing emissions by 35% compared to 2005 levels[84]. Given the regional and inter-federal governance structure in Belgium, policies and targets are often varying. The following are key measures and legislation across the three different regions:

- Brussels: The Brussels-Capital region has implemented the RENOLUTION strategy to decarbonise its residential sector, focusing on energy-efficient renovations, phasing out fossil fuels, and promoting renewable energy technologies[85]. Key components of this strategy include:
    - RENOLUTION Grants: Introduced in 2022, these grants consolidate previous energy and renovation subsidies into a unified scheme. They provide financial support for various energy-saving measures, including insulation, high-efficiency glazing, and the installation of renewable energy systems. The grants are accessible to a wide range of applicants, such as homeowners, tenants, and property managers.
        - *Recent drawback: premiums and grants for energy renovations are currently being drawn back and are slowly disappearing.*
    - Phasing out fossil fuel heating systems: The region has set a timeline to eliminate fossil fuel-based heating systems[86]:
        - 2025: Ban on installing oil- and gas-fired boilers in new buildings.

[81] EURAC: European Building Stock Analysis

[82] Cumbrera (2024), Energy performance certificates of housing in Brussels 2022, by rating, Brussels: EPCs of housing 2022, by energy rating | Statista

[83] CFP Green Buildings (2024), EU Taxonomy Alignment Methodology Document for Sustainable Residential Buildings in Belgium, https://www.argenta.eu/content/dam/argenta-eu-site/financial-information/2022/green-bonds/Methodology-Report-Argenta-Green-Loan-BE.pdf

[84] Klimaat.be

[85] Renolution Premiums

[86] Brussels renovation obligation approved by Parliament

    - 2030: Prohibition of oil- and gas-fired boilers in existing buildings undergoing major renovations.
    - 2035: Complete phase-out of oil- and gas-fired boilers in all buildings. These measures aim to reduce carbon emissions and encourage the adoption of renewable heating solutions.

- Flanders: Flanders has implemented a comprehensive set of policies and measures to decarbonise its residential sector, aiming to enhance energy efficiency and reduce GHG emissions. Key initiatives include:
  - Local Energy and Climate Pact (LEKP): Launched in 2022, the LEKP focuses on four key areas: urban greening, participatory energy projects, sustainable mobility, and efficient water management. The pact sets concrete objectives for municipalities, such as achieving 50 collective renovations per 1,000 housing units, with 25 of these reducing operational carbon use to zero (ZEB)[87].
  - Renovation obligation for residential buildings: Since January 1, 2023, Flanders mandates that residential properties with an Energy Performance Certificate (EPC) label of E or F must be renovated to achieve at least a D label within five years of transfer. This requirement will progressively tighten, with properties transferred after 2028 needing to reach a C label within five years, and those transferred after 2045 required to attain an A label[88].
    - *Recent drawback: Mandatory minimum C label for new transactions as of 2028 will be removed and put back at D.*
  - Phase-out of oil boilers in new buildings as of 2022[89].
  - EPC Label Premium for energy renovations: Homeowners undertaking significant energy renovations can apply for the EPC label premium. This incentive is available for homes with substandard energy performance (EPC label E or F) that, through renovation, achieve at least a C label within five years. The premium amount varies based on the achieved EPC label post-renovation.
    - *Recent drawback: Mandatory renovation within five years after deed signing, this will move up to six years.*
  - Renovation subsidies: The Flemish government offers financial incentives to homeowners for energy-efficient renovations. The 'Mijn VerbouwPremie' (My Renovation Premium) consolidates various subsidies into a single scheme, covering improvements such as insulation, high-efficiency glazing, and renewable energy installations. This streamlined approach simplifies the application process and encourages more residents to undertake energy-saving measures[90].
    - *Recent drawback: premiums and grants for energy renovations are currently being drawn back and are slowly disappearing.*
  - Zero-interest loans: To facilitate energy-efficient home improvements, Flanders provides zero-interest loans of up to €60,000 for eligible households. These can

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87 Local Climate Pact: Flanders

88 Renovation obligation in Flandres

89 EHI (2024), European Heating Industry: Heating Market Report 2023

90 EPC label premium for energy renovations (Fluvius)

be used for various energy-saving measures, including insulation, heating system upgrades, and the installation of renewable energy technologies[91].

- *Recent drawback: Currently the zero-interest loans are being drawn back and, like the renovation subsidies, are slowly disappearing.*

- Wallonia: Wallonia, as part of its comprehensive long-term renovation strategy, aims to decarbonise its building stock by 2050[92]. This strategy emphasises the importance of deep renovations to enhance energy efficiency and eliminate GHG emissions. Key measures include:
    - Wallonia is setting ambitious renovation targets, aiming to increase the volume and depth of housing renovations by 2050. It plans to triple or quadruple the renovation rate[93].
    - Phase-out of oil boilers in new buildings as of 2025[94].
    - One-stop-shop for building renovation: To facilitate and encourage energy-efficient renovations, Wallonia has established a one-stop-shop service that provides comprehensive support to households. This service offers guidance throughout the renovation process, including information on available financial incentives, technical assistance, and administrative support[95].
    - Wallonia also offers several financial incentives and support to homeowners undertaking energy-efficient renovations. These include grants, loans with interest discounts, and tax-incentives aimed at reducing the financial burden of renovations. A key programme includes the establishment of the Integrated Energy Renovation Support Service (SIARE), which consolidates fragmented support schemes to provide comprehensive assistance for energy renovations[96].
    - Wallonia engages in public-private partnerships to mobilise investments in building renovations. These collaborations aim to leverage private-sector expertise and resources to scale up renovation efforts and achieve energy-efficiency targets[97].

The impacts of financial measures are not quantified in the modelling and are used as indicative indicators of the availability of measures.

Parameters implemented in the model

Assessment of historical trends along with current policies and measures allowed the identification of specific parameters for each of the modelled scenarios as shown in Table 11.

[91] My Renovation Premium
[92] LTRS Wallonia
[93] LTRS Wallonia
[94] EHI (2024), Heating Market Report 2023, European Heating Industry: Heating Market Report 2023
[95] European Commission: one-stop-shop for households - Wallonia
[96] LTRS – Wallonia - ANNEXES
[97] LTRS – Wallonia - ANNEXES

Table 11: Parameters for modelled scenarios – Belgium

Scenario	Parameter	Description
BAU	**Renovation rate**	Historically, Belgium's annual renovation rate is estimated to be below the EU average of 1%, which is still below the threshold of achieving any of the decarbonisation targets. This is assumed to still be the case in the BAU scenario with a slight increase to 1.3% from 2030 onwards to account for the natural uptick of renovations.
	Renovation depth	Historically, shallow non-energy related renovations have dominated the Belgian buildings sector. For future BAU scenario projections, an increase uptake of moderate and deep renovations is assumed with most annual renovations allocated for medium renovations achieving an average of 50-60% energy savings.
	Heating systems exchange	Historically natural gas-condensing boilers were the most sold technology for heating purposes. For future BAU scenario projections, the following was assumed: • **New buildings:** complete phase-out of oil boilers and natural gas systems as a result of the effective regulatory bans on installations of oil and gas systems in new buildings from 2025. An increased share of biomass, hybrid and electric heat pumps. • **Existing buildings:** continued use of oil boilers and natural gas for system replacements until 2030. Other new systems include biomass, district heating, hybrid and regular heat pumps.
POLICY	**Renovation rate**	The renovation rate for the POLICY scenario is estimated to average 2.0% accounting for regional goals aimed at increasing the uptake of deep renovations and reflecting the measures on the ground, considering recent policy and regulatory drawbacks. The renovation rate is assumed to fully materialise by 2030, with a linear uptake expected between 2025 and 2030 to reflect a realistic increase.
	Renovation depth	An assumed increase uptake of moderate and deep renovations, with most annual renovations allocated for medium renovations achieving an average of 50-60% energy savings. The shares of ZEB and ZEB restricted renovations of the total annual renovations are assumed to reach around 5% each by 2030 and 10% each by 2050. This is driven by the emphasis on deep renovations in the Flanders and Brussels-capital regions.
	Heating systems exchange	• **New buildings:** complete phase-out of oil boilers and natural gas systems because of the effective regulatory bans on installations of gas systems in new buildings. There is a significant increase in

		the shares of hybrid and regular heat pumps compared to the BAU scenario. The remaining shares are allocated for district heating and a slight increase of biomass and solar thermal. • **Existing buildings:** complete phase-out of oil boilers and natural gas for system replacements by 2030. Increased shares of electric- and hybrid heat pumps with biofuels. Other new systems include district heating and the increased uptake of biomass and solar thermal systems for DHW generation.
NET-ZERO	**Renovation rate**	The renovation rate for the NET-ZERO scenario is estimated to average 3%, accounting for the maximum realistically achievable rate without exceeding technical, social, and financial feasibility limits for homeowners[98].
	Renovation depth	According to a comprehensive European study[99] on actual renovation rates and depth, it is estimated that about 7-8% of total floor area for Belgian residential buildings undergoes light, medium or deep renovations every year. Given the dominance of light renovations[100] across all EU countries, the study concluded that to improve overall renovation efficiency, buildings undergoing energy renovations must achieve greater renovation depth. At the same time, the total renovation capacity of the construction sector is limited, which means the annual renovated floor area will need to decrease as average renovation depths increase. This insight was later applied in the impact assessment preceding the European Commission proposal for EPBD 2024.
	Heating systems	• **New buildings:** complete phase-out of oil boilers and natural gas systems as of 2025[102]. A significant increase in the shares of electric- and hybrid heat pumps with biofuels compared to the BAU scenario.

[98] This aligns with a Guidehouse study for the European Commission underpinning the EPBD impact assessment (see EPBD IA), where technical, social and economic parameters were assessed in depth for five European zones – East, West, North, North East South. The High-I and High-II scenarios (see EPBD IA) partially used renovation rates > 3% annually renovated floor area. However, for the actual EPBD proposal, it was concluded that maximum renovation rates of approx. 3%, as used in the 'Moderate' scenario, are a more realistic combination with average-depth whole-building renovations. This avoids over-burdening any of the assessed parameters (e.g. availability of supply chains, public acceptance, financial support, burden to the electricity grid). At the same time, it requires more effort in off-site decarbonisation to adhere to a net-zero emission pathway by 2050 than assumed in High-I and High-II scenarios. Due to the many boundary conditions determining the exact future renovation rates, even in the EPBD IA, no differentiation was applied between European zones.

[99] Hermelink, A., Schimschar, S., Esser, A., Dunne, A., Meeusen, T., Quaschning, S., Wegge, D., Offermann, M., John, A., Reiser, M., Pohl, A., & Grözinger, J. (2019). Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU: Final report. Research report prepared for European Commission, DG Energy. Ipsos; Guidehouse (formerly Navigant). https://op.europa.eu/en/publication-detail/-/publication/97d6a4ca-5847-11ea-8b81-01aa75ed71a1/language-en/format-PDF/source-119528141

[100] The study revealed a dominance of light renovations (defined to save between 3-30% of primary energy). However, the actual savings achieved were at the lower end of that range. Specifically, the EU average for primary energy savings was determined to be 13%, as shown in Table 4 in that study).

[102] This is driven by several reasons, including local regulatory bans and EPBD bans on financial incentives for fossil fuel stand-alone systems, making fossil fuels systems an unattractive solution. This also paves the road for new buildings to align with the EPBD requirement that all new buildings be NZEB by 2030. Furthermore, the growing share of heat pumps is most suited for new buildings to avoid high electricity loads and prevent overburdening the electricity grid.

	exchange [101]	For SFH, up to 35% and 50% by 2030 and 2050, respectively, and for MFH, up to 15% and 40% by 2030 and 2050 respectively. The remaining shares are allocated for district heating and biomass. • **Existing buildings:** complete phase-out of natural gas for system replacements well before 2030[103]. Significantly increased shares of hybrid and regular heat pumps with biofuels in proportion with the diminishing shares of fossil fuel systems. For SFH up to 35% and 60% by 2030 and 2050, respectively, and for MFH up to 30% and 40% by 2030 and 2050 respectively. Other new systems include biomass, district heating, and increased uptake of solar thermal systems for DHW generation. • Increased use of renewable fuels and a complete replacement of natural gas by 2040 from all existing systems[104]. • Complete phase-out of oil boilers and oil-based systems by 2040 from all existing systems. • Accelerated decarbonisation rates for district heating, achieving full decarbonisation by 2040[105].

[101] The assumptions and changes here refer to the affected systems due to renovation activities and heating systems exchange rates, and are not representative of the overall heating systems stock currently installed in the building stock. See Figure 3, section 2.3.1: *Heating systems stock* for heating systems stock development. The allocated shares are aligned with the proposed heat pumps uptake rate in the EPBD-IA for the western EU zone, with modifications to reflect the Belgian situation and current uptake of heat pumps.

[103] Setting 2030 as the cut-off year for new fossil-fuel system replacements is driven by the need to fully decarbonise the building sector by 2050 and avoid lingering fossil-fuel systems, which typically have a lifetime of up to 20 years, in the building stock.

[104] Assumptions are set as part of the authors interpretation of the FF55 2040 package. Refer to ch. 2.2.3 for further details.

[105] Assumptions are set as part of the authors interpretation of the FF55 2040 package. Refer to ch. 2.2.3 for further details.

5.2.2 Germany

Final energy consumption breakdown by type of end-use across the residential sector

In Germany, heating and DHW needs were responsible for around 83% of the total residential sector energy consumption, highlighting the crucial role that heating and DHW play in decarbonising the residential sector. Figure 16 provides an overview of the final energy consumption by type of end-use in Germany.

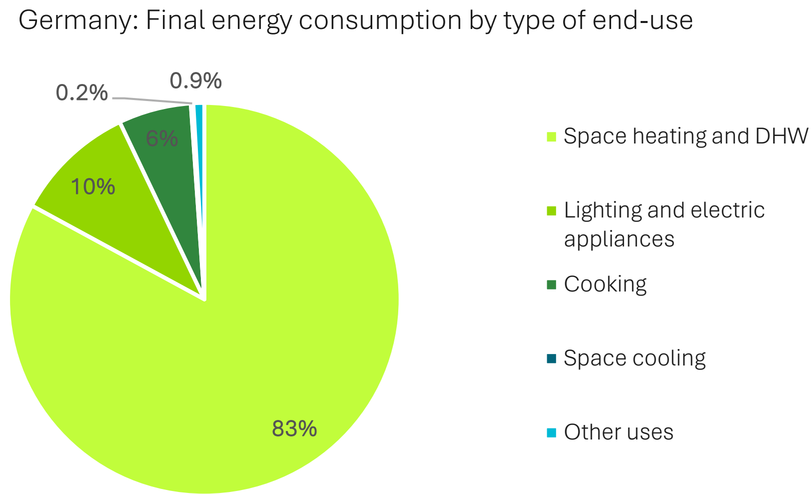

Figure 16: Share of final energy consumption per type of end-use – Germany
Adapted from EUROSTAT – Energy consumption in households[106]

Useful floor area distribution

Distribution of the floor area in the German residential building sector is illustrated in Figure 17. Germany's residential building stock encompasses 3.8 billion m² of useful floor area, predominantly occupied by SFHs, which represent about 61% of the total. SMFHs contribute another 31%, while LMFHs make up the remaining 8%[107].

Growth in housing supply is relatively slow, with new construction adding around 0.8% to the building stock each year and a demolition rate of around 0.08% annually[108]. This construction rate is insufficient to keep up with population growth and housing demand. Currently, Germany is facing a significant housing shortage, with demand far exceeding available supply. Recent estimates indicate a deficit of over 800,000 apartments nationwide, and this number is still rising[109].

[106] European Commission (2024), Energy consumption in households by type of end-use, Energy consumption in households

[107] EU Building Stock Observatory

[108] Destatis, Federal Statistical Office of Germany. Construction and demolition rates were estimated as a function of the total floor area.

[109] German housing crisis

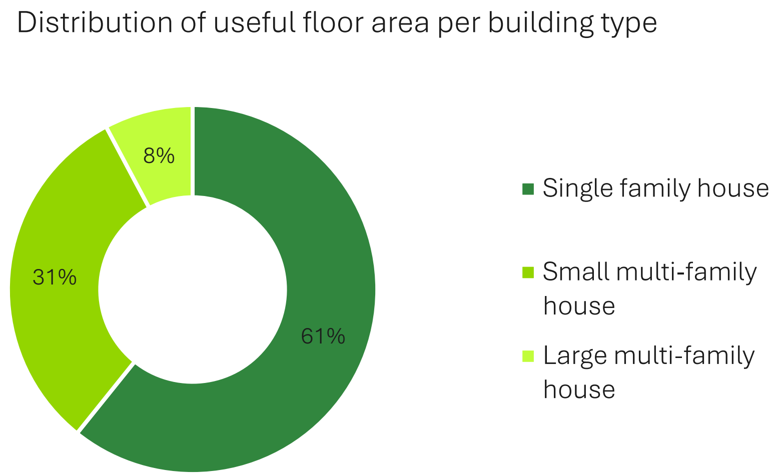

Figure 17: Distribution of useful floor area per building type in Germany
Adapted from EU Building Stock Observatory database[110]

Figure 18 illustrates the distribution of building types by age group in Germany, showing how the prevalence of certain building types has varied over time. The data sources and methodology used to generate this distribution are based on two main datasets. The base data is from IWU[111], which covered construction data up to 2013. To fill the data gap from 2013 to 2020, supplementary data from the German Statistical Office[112] was used. This includes recent construction and demolition statistics to reflect changes in the building stock up to 2020.

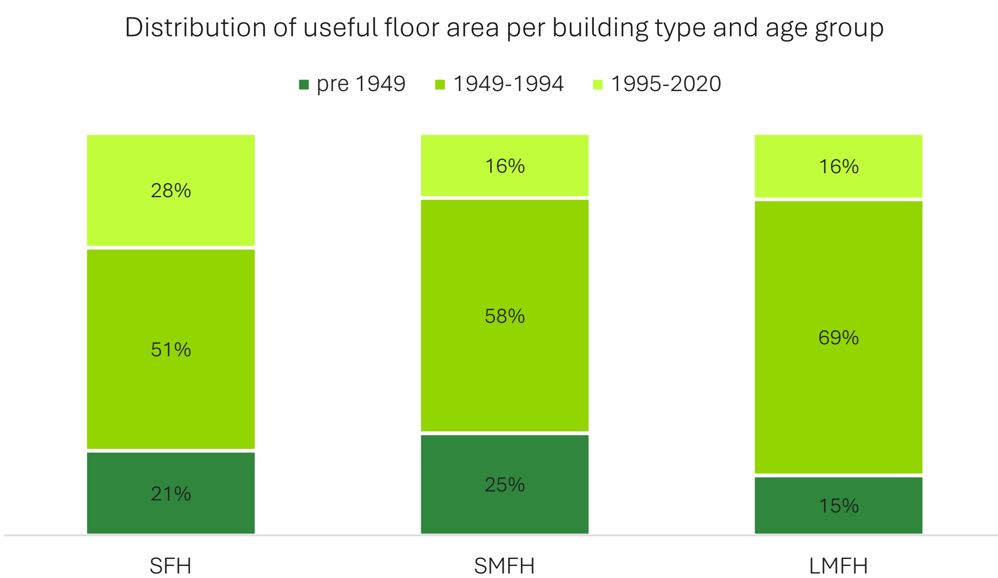

Figure 18: Distribution of building types per age group in Germany
Adapted from EU Building Stock Observatory database[113]

[110] EU Building Stock Observatory
[111] Institut Wohnen und Umwelt GmbH
[112] Destatis, Federal Statistical Office of Germany
[113] EU Building Stock Observatory

Current state of renovation

Figure 19 shows the distribution of buildings by renovation status in Germany. The data, drawn from the IWU report[114], provides a detailed look at the renovation status of residential buildings by type and age. It highlights the concentration of renovation efforts and identifying trends across different building types.

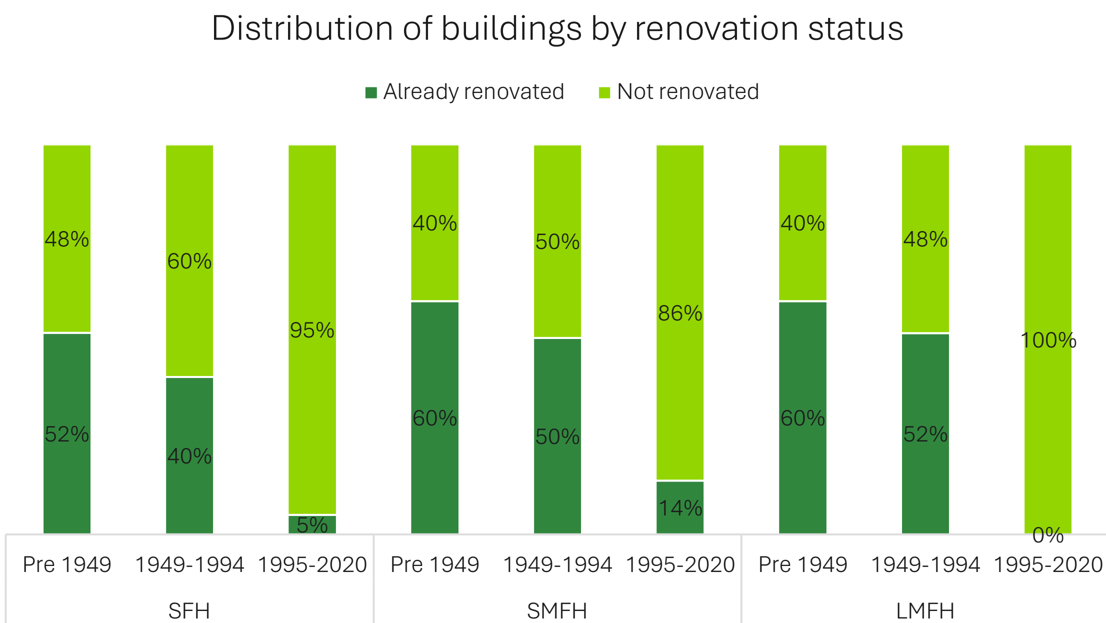

Figure 19: Distribution of buildings by renovation status in Germany

Heating systems distribution

Figure 20 shows the distribution of heating systems across the German residential building sector. It underscores the dominance of gas- and oil-based heating, presenting significant challenges for decarbonisation efforts. In SFHs built before 1949, 48% of the systems rely on gas heating, while 33% are oil based, complemented by smaller shares for biomass (7%) and district heating (5%). This pattern shifts slightly in SFHs built from 1949-1994, where gas reliance rises to 54%, oil maintains a presence at 32%, and minor shares exist for wood heating (6%) and district heating (4%). For more modern SFHs (1995-2020), gas remains dominant at 54%, although oil usage drops to 12%. There is notable growth in heat pumps and hybrid heat pumps at 24%, indicating an emerging trend toward lower-carbon solutions in newer buildings.

In SMFHs, particularly those built before 1949, gas heating is even more prevalent, covering 63% of systems, with oil heating making up 22%, and district heating at 11%, reflecting a higher reliance on centralised heating solutions. SMFHs built from 1949-1994 display a similar dependency on gas (60%) but show a more substantial uptake in district heating (19%), suggesting a partial shift towards lower-carbon infrastructure. In buildings constructed from 1995-2020, gas usage falls to 38%, and the proportion of district heating rises to 26%, complemented by a 14% share of direct electricity-based systems and an 8% share of heat pumps and hybrid heat pumps.

[114] Institut Wohnen und Umwelt GmbH

For LMFHs, the trend is similar, with a consistent reliance on gas (63%) and oil (22%) for buildings pre-dating 1949, while district heating accounts for 11% of heating solutions. LMFHs built between 1949-1994 also show gas dominance at 60%, district heating at 19%, and minor shares of wood and heat pump usage. In more modern LMFHs (1995-2020), gas usage declines to 38%, district heating usage increases to 26%, heat pumps and hybrids achieve an 8% share, and direct electricity-based heating systems account for 14%. This mirrors trends in SMFHs, showing a gradual diversification of heating sources.

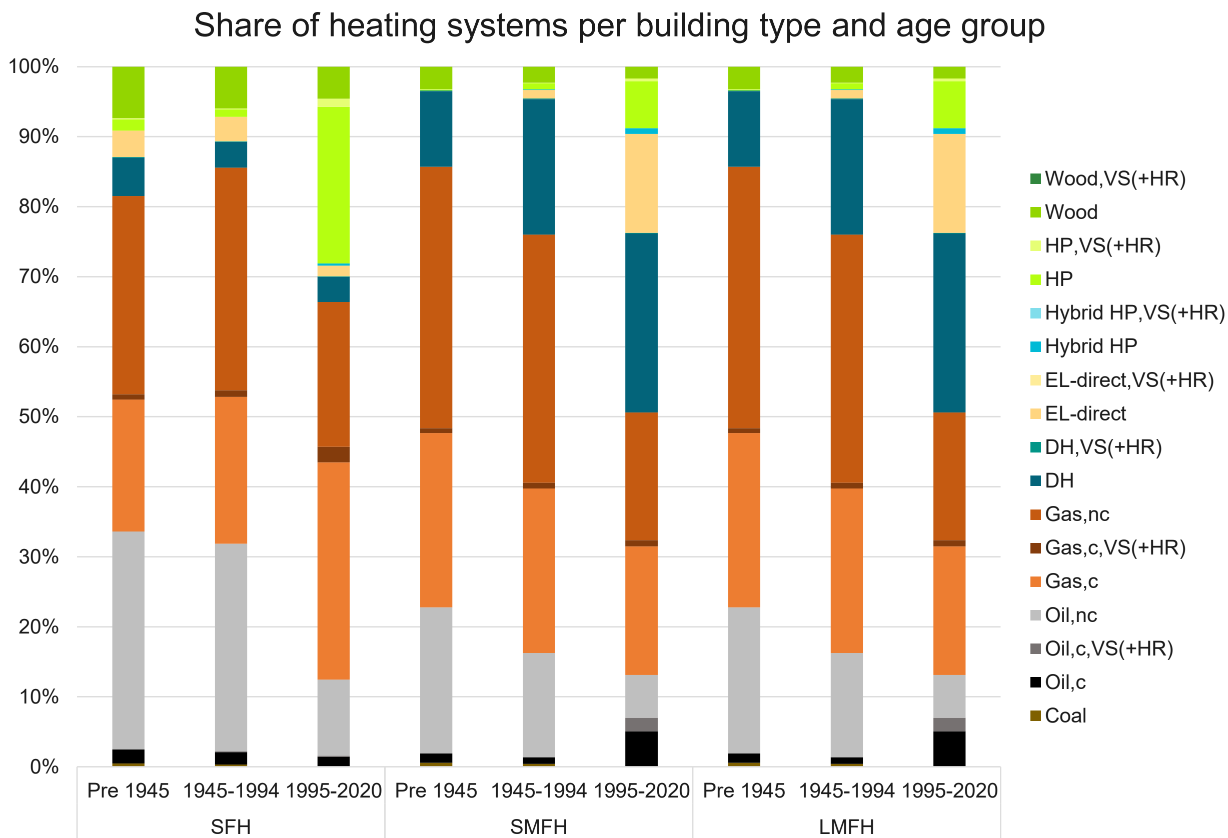

Figure 20: Share of heating systems per building type and age group in Germany
Adapted from EPBD-Impact Assessment Study and European Heating Industry

The prevalent of reliance on gas and oil across all building types and age groups indicates a need for high-level policy interventions and substantial upgrades to effectively decarbonise Germany's building sector. Expanding district heating infrastructure, scaling up heat pump adoption, and transitioning away from direct fossil fuel-based heating systems are essential steps toward achieving lower-carbon residential buildings. These trends reveal opportunities for incentivising modernised, renewable heating technologies in both new builds and existing structures, particularly in multi-family buildings where centralised systems could potentially yield faster decarbonisation results.

Building stock energy performance

Building stock energy performance and final energy consumption is influenced by several factors, namely building characteristics (age, insulation quality, size, construction material), energy systems and appliances, user behaviour, climate and weather, energy efficiency measures, and other external factors. Overall, the building stock in Germany varies significantly in terms of final energy consumption across the different construction periods and witnesses a steep decline in average final energy demand from pre-1945 to buildings constructed post-2010. Buildings built pre 1945 have an average final energy demand consumption of 280 kWh/m^{2}a, which drops gradually to around 200 kWh/m^{2}a for buildings throughout the 1970s. Buildings built post 2010 show a significant reduction in final energy demand, with almost half the average final energy demand of the buildings built in the 1970s reaching an average of 89 kWh/m^{2}a[115].

From the perspective of this paper, buildings with a final energy consumption of 200 kWh/m^{2}a and above are considered as worst-performing. Based on this criterion, all buildings constructed before the 1980s in Germany are worst-performing and in need of energy renovations.

The frequency distribution of building efficiency EPC classes according to the final energy demand in the German building stock (MFH, and detached and semidetached houses) is as follows: 7% class A or higher, 7% class B,+ (4%), A (3%), (7%) 12% class C, (12%) and over 70% of buildings are class D or lower D (15%), E (14%), F (15%), G (13%), H (17%)[116].

Policies and measures

Germany has established specific goals and targets within its regulatory mandates to decarbonise the residential heating sector, aiming for climate neutrality by 2045. Key mandates and their objectives include:

- Building Energy Act (Gebäudeenergiegesetz – GEG): The GEG, which went into force in November 2020, consolidates previous energy regulations and standard-setting for energy efficiency in buildings. Two key mandates are as follows:
    - Renewable energy requirement: Starting January 1, 2024, all newly installed heating systems must utilise at least 65% renewable energy. This applies to both new constructions and existing buildings undergoing heating system replacements.
        - Alternatively, they can opt for an alternative standard solution to comply with the obligation. This includes connecting to a heating grid, switching to an electric heat pump, electrical heater, a hybrid heating system (e.g. Hybrid heat pump), solar thermal energy or gas heating systems, as long as they are H_2-ready with an existing legally binding plan for a hydrogen network.
        - However, there are exemptions to this mandate. Homeowners aged 80 and above are exempt from replacing existing heating systems. This exemption applies until the property is sold or inherited, at which point the new owner must comply with the regulations within a two-year period[117].
    - The use of fossil fuels in heating systems is to be discontinued by December 31, 2044, mandating that all buildings be heated in a climate-neutral manner from 2045 onwards. The GEG outlines a gradual phase-out of fossil fuel-based heating systems[118].

[115] EURAC: European Building Stock Analysis

[116] European Union (2020), Long-Term Renovation Strategy of the Federal Government, https://energy.ec.europa.eu/system/files/2020-09/de_2020_ltrs_official_en_translation_0.pdf

[117] German Government – Building Energy Act

[118] German Government – Building Energy Act

- Climate Protection Act (Klimaschutzgesetz): The Climate Protection Act, enacted in 2021, sets binding targets to reduce GHG emissions by 65% by 2030 compared to 1990 levels and achieve climate neutrality by 2045. It mandates sector-specific emission reductions, including the building sector[119].
- Renewable Energy Heat Act (Erneuerbare-Energien-Wärmegesetz - EEWärmeG): This act promotes the use of renewable energy in heating and cooling. It requires new buildings to source a portion of their heating and cooling energy from renewable sources, such as solar thermal, biomass, or geothermal energy. This was later integrated into the GEG[120].
- Local Heat Planning Act (Wärmeplanungsgesetz - WPG): This forthcoming legislation will require municipalities to develop heat plans to decarbonise local heating systems, promoting district heating networks and the integration of renewable energy sources[121].
- Federal Funding for Energy-Efficient Buildings (Bundesförderung für effiziente Gebäude - BEG): Launched in 2021, the BEG offers financial incentives for energy-efficient construction and renovation. It provides grants and loans with interest discounts for measures such as insulation, window replacement, and the installation of renewable energy heating systems[122].

  Not assessed directly in this paper – Only indicative to the parameters definition and counted as a measure contributing to the fulfilment of other tangible measures and policies.
- Tax Incentives for Energy-Efficient Renovations: Homeowners can receive tax deductions of up to 20% of renovation costs for energy efficiency improvements, spread over three years. Eligible measures include upgrading heating systems, installing new windows, and insulating roofs and external walls[123].

  Not assessed directly in this paper – Only indicative to the parameters definition and counted as a measure contributing to the fulfilment of other tangible measures and policies.
- Market Incentive Programme (Marktanreizprogramm – MAP): The MAP provides grants for the installation of renewable heating systems, including heat pumps, biomass boilers, and solar thermal systems. It aims to increase the share of renewable energy in the heating sector[124].

  Not assessed directly in this paper – Only indicative to the parameters definition and counted as a measure contributing to the fulfilment of other tangible measures and policies.
- KfW Efficiency House Standards: The KfW development bank offers financial support for energy-efficient construction and renovation through its 'Efficiency House' standards. These standards define specific energy performance levels, with higher efficiency levels receiving greater financial incentives[125].

  Not assessed directly in this paper – Only indicative to the parameters definition and counted as a measure contributing to the fulfilment of other tangible measures and policies.

Financial measure impacts are not quantified in the modelling and are used as an indicative indicator to the availability of measures.

[119] BMUV (2019), Bundes-Klimaschutzgesetz (KSG), BMUV - Climate Protection Act
[120] German Government – Building Energy Act
[121] German Government – Local Heat Planning Act
[122] BAFA – Federal Funding for Energy Efficient Buildings
[123] German Government – Building and Housing
[124] German Government – Building and Housing
[125] The KfW Efficiency House standards: KfW 85, 75, 55, 40 (EE), (NH) and Plus

Parameters implemented in the model

Assessment of historical trends along with current policies and measures allowed the identification of specific parameters for each of the modelled scenarios as shown in Table 12.

Table 12: Parameters for modelled scenarios – Germany

Scenario	Parameter	Description
BAU	**Renovation rate**	Historically, Germany's annual renovation rate is estimated to be around the EU average of 1%, which is still below the threshold of achieving any of the decarbonisation targets. It is assumed that this will remain the case in the BAU scenario, with a slight increase to 1.5% from 2030 onwards to account for the natural uptick of renovations.
	Renovation depth	Historically shallow non-energy-related renovations have dominated the German buildings sector. For future BAU scenario projections, an increase uptake of moderate and deep renovations is assumed with most annual renovations allocated for medium renovations achieving an average of 50-60% energy savings.
	Heating systems exchange	Historically, natural gas condensing boilers and oil boilers were the most sold technology for heating purposes. For future BAU scenario projections, the following was assumed: • **New buildings:** all new gas-based systems will use at least 65% of renewable energy, either through biofuel blends or hybrid systems. An increased focus on heat pumps, district heating and biomass systems. • **Existing buildings:** continued use of natural gas for system replacements, with at least 65% of that through biofuel blends or hybrid systems. Increased focus on district heating, hybrid and regular heat pumps and biomass.
POLICY	**Renovation rate**	The renovation rate for the POLICY scenario is estimated to be 2.2% on average, accounting for several policy measures on the ground, namely, regulatory enforcements. The renovation rate is expected to fully materialise by 2030, with a gradual, linear uptake from 2025 to 2030 to reflect a realistic growth trajectory.
	Renovation depth	An assumed increase of moderate and deep renovations with most annual renovations allocated for medium renovations, achieving an average of 50-60% energy savings. The shares of ZEB and ZEB-restricted renovations of the total annual renovations are assumed to reach around 5% each by 2030 and 10% each by 2050.

	Heating systems exchange	• **New buildings:** All new gas-based systems will use at least 65% renewable energy, either through biofuel blends or hybrid systems. A significant increase in the shares of hybrid and regular heat pumps compared to the BAU scenario. The remaining shares are allocated for district heating and biomass. • **Existing buildings:** All new gas-based systems will use at least 65% renewable energy, either through biofuel blends or hybrid systems. A significant increase in the shares of hybrid and regular heat pumps compared to the BAU scenario. The remaining shares are allocated for district heating and biomass.
NET-ZERO	**Renovation rate**	The renovation rate for the NET-ZERO scenario is estimated to average 3%, representing the highest realistically achievable rate without exceeding technical, social, and financial feasibility limits for homeowners[126].
	Renovation depth	According to a comprehensive European study[127] on actual renovation rates and depth for German residential buildings, it was estimated that about 4% of total floor area undergoes light, medium or deep renovations every year. Given the dominance of light renovations[128] across all EU countries, the study concluded that to improve overall renovation efficiency, buildings undergoing energy renovations must achieve greater renovation depth. At the same time, total renovation capacity of the construction sector is limited, meaning annual renovated floor area will need to decrease at increasing average renovation depths. This insight was later applied in the impact assessment preceding the European Commission proposal for EPBD 2024.

[126] This aligns with a Guidehouse study for the European Commission underpinning the EPBD impact assessment (see EPBD IA), where technical, social and economic parameters were assessed in depth for five European zones - East, West, North, North East South. The High-I and High-II scenarios (see EPBD IA) partially used renovation rates > 3% annually renovated floor area. However, for the actual EPBD proposal, it was concluded that maximum renovation rates of approx. 3% as used in the ‘Moderate’ scenario are a more realistic combination with average average-depth whole-building renovations. This avoids over-burdening any of the assessed parameters (e.g. availability of supply chains, public acceptance, financial support, burden to the electricity grid). At the same time, it requires more effort in off-site decarbonisation to adhere to a net-zero emission pathway by 2050 than assumed in High-I and High-II scenarios. Due to the many boundary conditions determining the exact future renovation rates, even in the EPBD IA, no differentiation was applied between European zones.

[127] Hermelink, A., Schimschar, S., Esser, A., Dunne, A., Meeusen, T., Quaschning, S., Wegge, D., Offermann, M., John, A., Reiser, M., Pohl, A., & Grözinger, J. (2019). Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU: Final report. Research report prepared for European Commission, DG Energy. Ipsos; Guidehouse (formerly Navigant). https://op.europa.eu/en/publication-detail/-/publication/97d6a4ca-5847-11ea-8b81-01aa75ed71a1/language-en/format-PDF/source-119528141

[128] The study revealed a dominance of light renovations (defined to save between 3-30% of primary energy). However, the actual savings achieved were at the lower end of that range. Specifically, the EU average for primary energy savings was determined to be 13%, as shown in Table 4 in that study).

	Heating systems exchange[129]	• **New buildings:** complete phase-out of natural gas systems as of 2025[130]. A significant increase in the shares of electric and hybrid heat pumps with biofuels compared to the BAU scenario. For SFH up to 60% and 70% by 2030 and 2050, respectively, and for MFH up to 50% and 60% by 2030 and 2050 respectively. The remaining shares are allocated for district heating and biomass. • **Existing buildings:** complete phase-out of natural gas for system replacements well before 2030[131]. Significantly increased shares of hybrid and regular heat pumps with biofuels. For SFH up to 50% and 55% by 2030 and 2050, respectively, and for MFH up to 40% and 50% by 2030 and 2050 respectively. Other new systems include biomass, district heating and increased uptake of solar thermal systems for DHW generation. • Increased use of renewable fuels and a complete replacement of natural gas by 2040 from all existing systems[132]. • Accelerated decarbonisation rate of district heating achieving full decarbonisation by 2040[133].

[129] The assumptions and changes here refer to the affected systems due to renovation activities and heating systems exchange rates, and are not representative of the overall heating systems stock currently installed in the building stock. See Figure 3, section 2.3.1: *Heating systems stock* for heating systems stock development. The allocated shares are aligned with the proposed heat pumps uptake rate in the EPBD-IA for the western EU zone, with modifications to reflect the German situation and current uptake of heat pumps.

[130] This is driven by several reasons as follows: Local regulatory bans in addition to EPBD bans on financial incentives for fossil fuel stand alone systems thus denoting fossil fuels systems as an unattractive solution. This also paves the road for new buildings to align with the EPBD requirement of all new buildings being NZEB by 2030. Furthermore, the growing shares of heat pumps are most suited for new buildings to avoid high electricity loads and avoid overburdening the electricity grid. For further assessment refer to

[131] Setting 2030 as the cut off year for fossil fuels systems new replacements is driven by the need to fully decarbonise the buildings sector by 2050 and to avoid lingering fossil fuels systems that have a typical lifetime up to 20 years in the building stock.

[132] Assumptions are set as part of the authors interpretation of the FF55 2040 package. Refer to ch. 2.2.3 for further details.

[133] Assumptions are set as part of the authors interpretation of the FF55 2040 package. Refer to ch. 2.2.3 for further details.

5.2.3 Netherlands

Final energy consumption breakdown by type of end-use across the residential sector

In the Netherlands, heating and DHW accounted for around 80% of the total residential sector energy consumption, highlighting their crucial role in decarbonising the residential sector. Figure 21 provides an overview of the final energy consumption by type of end-use in the Netherlands.

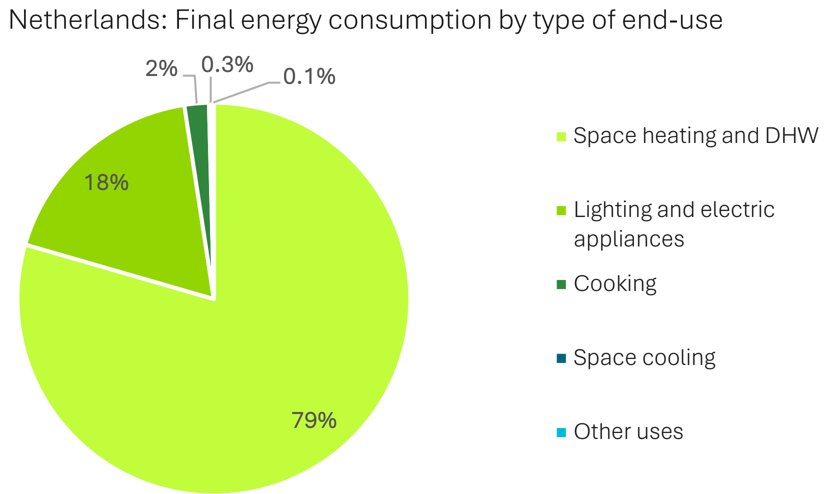

Figure 21: Share of final energy consumption per type of end-use – Netherlands
Adapted from EUROSTAT – Energy consumption in households[134]

Useful floor area distribution

The Dutch residential sector covers an area of about 624 Mm^2 of useful floor area[135]. The majority of the homes are SFHs, making up 85% of the total useful floor area. Figure 22 provides an overview of the useful floor area distribution per residential building type in the Netherlands.

Over the past 10 years, the average rate of new building has been about 0.74%[136], and the demolition rate estimated to be around 0.15%[137]. Despite the construction rate being well over the demolition rate, the Netherlands is currently facing a significant housing shortage with demand far surpassing supply (recent estimates indicate a shortage of over 400,000 homes)[138]. This low turnover rate means efforts to reduce carbon emissions will have to focus mainly on the buildings that are already there, and new buildings should be built at high standards with NZEB to contribute to reducing the overall energy use.

[134] European Commission (2024), Energy consumption in households by type of end-use, Energy consumption in households

[135] EU Building Stock Observatory

[136] Based on the average construction rate over the past 10 years: Dwellings and non-residential stock

[137] Based on the average demolition rate over the past 10 years: Dwellings and non-residential stock

[138] Dutch housing shortage rises to over 400,000 as population growth outstrips construction

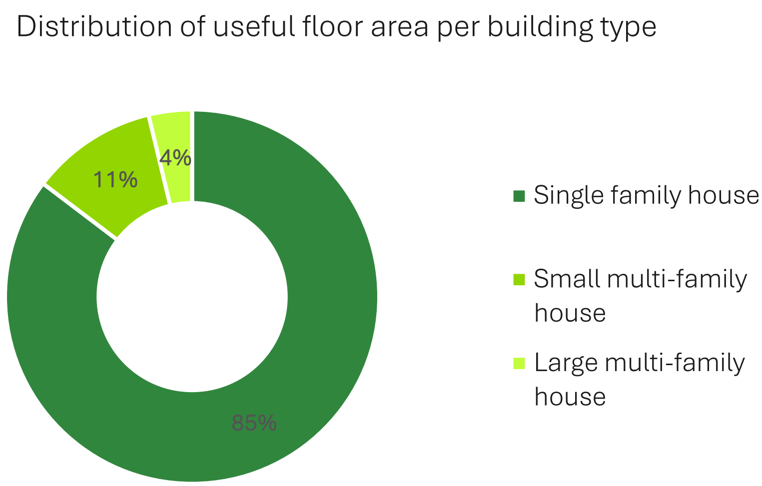

Figure 22: Useful floor area distribution per building type in the Netherlands
Adapted from EU Building Stock Observatory database[139]

Figure 23 provides an overview of the buildings' distribution across different age groups.

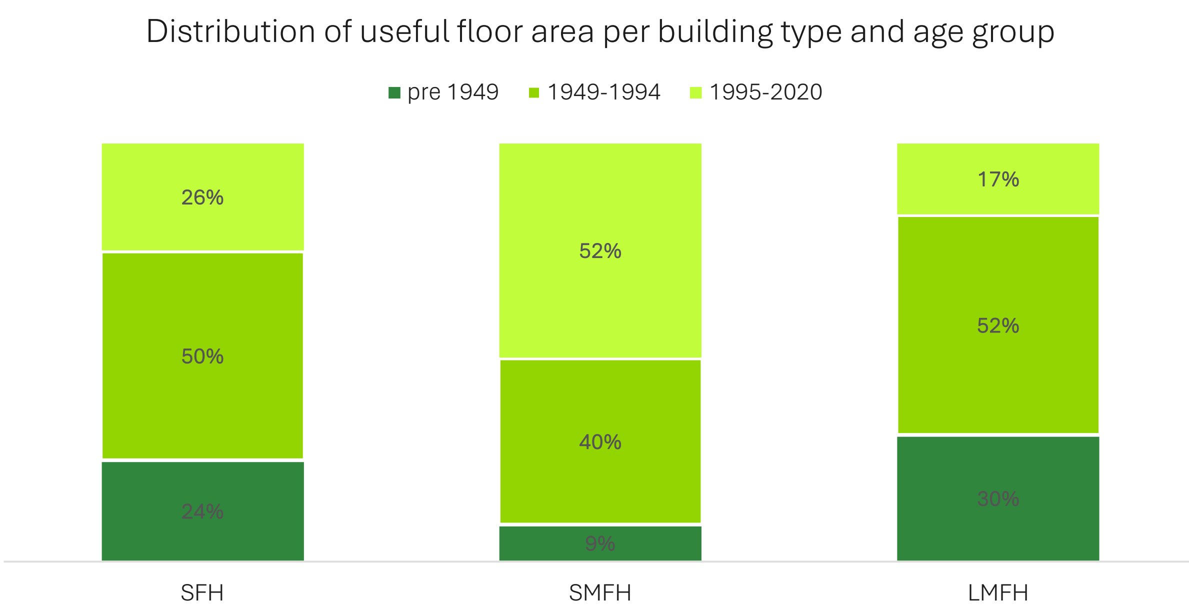

Figure 23: Distribution of reference building type per age group in the Netherlands
Adapted from EU Building Stock Observatory database[140]

139 EU Building Stock Observatory
140 EU Building Stock Observatory

Current state of renovation

Figure 24 illustrates a breakdown of the current renovation status per building type and age group. The distribution of renovated buildings across age groups have been estimated based on the renovation status distribution approximated in the EPBD Impact Assessment[141] project for the western Europe zone.

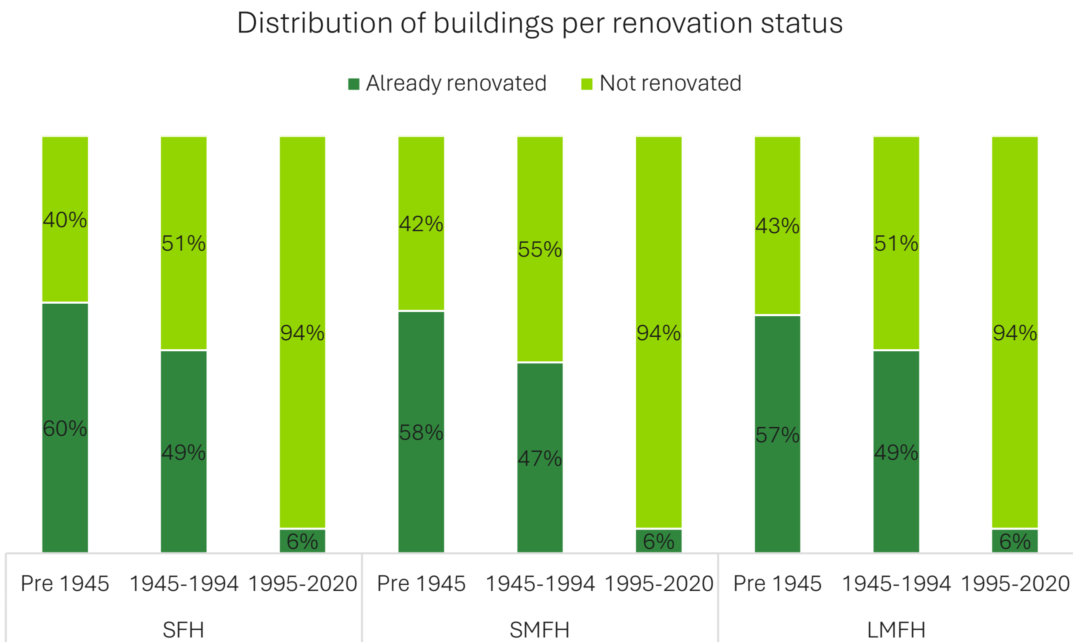

Figure 24: Current state of renovation distribution per building type and age group in the Netherlands

Heating systems distribution

The analysed data for space heating (SH) and DHW in the Dutch residential sector is defined by an individual SH and DHW system. Combined boilers are utilised across all building types and development periods. Furthermore, the data indicate that condensing boilers for DHW requirements are predominantly used in apartment buildings, regardless of the construction eras[142] [143]. Natural gas is extensively utilised across all evaluated building types for space heating and DHW requirements. The predominant technologies for SH and DHW are central gas condensing boilers, followed by smaller presence of heat pumps, and hybrid heat pumps[144]. Figure 25 illustrates the current distribution of heating systems by building type and age group in the Netherlands.

[141] Technical assistance for policy development and implementation on buildings policy and renovation - support for the ex-ante impact assessment and revision of Directive 2010/31/EU on energy performance of buildings.

[142] Episcope – Netherlands Country Page: NL The Netherlands

[143] EURAC: European Building Stock Analysis

[144] EHI (2024), Heating Market Report 2023, European Heating Industry: Heating Market Report 2023

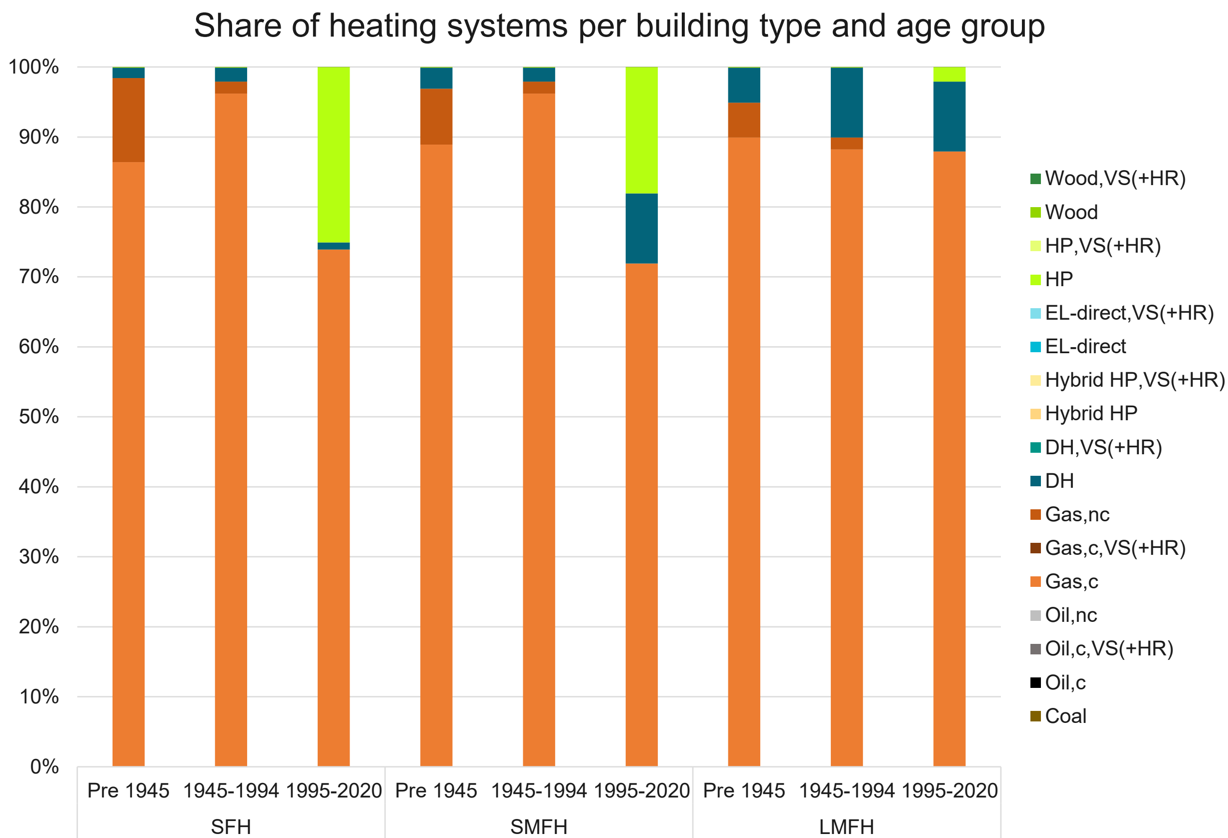

Figure 25: Share of heating systems per building type and age group in the Netherlands
Adapted from EPBD-Impact Assessment Study and European Heating Industry

Building stock energy performance

Building stock energy performance and final energy consumption is influenced by several factors namely, building characteristics (age, insulation quality, size, construction material), energy systems and appliances, user behavior, climate and weather, energy efficiency measures and other external factors. Overall, the building stock in the Netherlands shows significant variation in energy consumption across different construction periods. There is a steep decline in average final energy demand from buildings constructed before 1945 to those built after 2010. Buildings built pre 1980s have an average final energy demand consumption of slightly lower than 200 kWh/m^{2}a, which drops gradually to around 130 kWh/m^{2}a, 90kWh/m^{2}a, 70 kWh/m^{2}a and 40 kWh/m^{2}a for buildings constructed in the 1980s, 1990s, early 2000s and post 2010, respectively[145].

From the perspective of this paper, buildings with a final energy consumption of 200 kWh/m^{2}a and above are considered worst-performing. Based on this criterion, all buildings constructed before 1980s in the Netherlands can be considered worst-performing and in need of energy renovations.

The distribution of the Dutch residential buildings across the different EPC labels in terms of primary energy demand is as follows: EPC label A and above account for 23.1%, B label for

[145] EURAC: European Building Stock Analysis

10%, C label for 15%, D label for 6.4% E label for 4%, F label for 2.4% and G label for 2.4% of the total building stock with the remaining ~ 37% of the building stock with no EPC labels.

Policies and measures

The Netherlands holds the position of the most dependent market on natural gas for heating purposes among the EU27 markets with natural gas accounting for more than 85% of the energy used for space heating in residential buildings[146]. As a result of this, the Dutch policy response is centred around the phase-out of natural gas as the norm for heating systems in the residential sector.

The Dutch Climate Act 'Klimaatakoord' sets the pace for decarbonisation goals and measures. When the climate accord was published in 2019, it set goals for GHG-emissions reduction of 49% and 95% in 2030 and 2050 respectively, compared to 1990 levels[147]. The level of ambition on this has since increased to match the EU fit-for-55 levels, aiming for reductions of 55%, 70%, 80%, and climate neutral by 2030, 2035, 2040 and 2050 respectively. Additionally, the act aims to fully decarbonise the heating sector from natural gas by 2050, with an intermediate goal of having 1.5 million households free from natural gas by 2030[148]. To achieve these targets, the Dutch government has implemented the following measures:

- An area-specific approach focusing on the heating transition: The Dutch government will work closely with municipalities to identify optimal solutions to phase-out natural gas per local context. Through financial and technical support, local municipalities will work on developing neighbourhood-by-neighbourhood action plans for sustainability measures. The Dutch government plans to provide 500,000 new connections to district heating networks in existing buildings by 2030.
- As part of the Dutch Climate Act, it is mandatory that around 450,000 homes from the social housing sector become natural-gas free by 2030. This is considered achievable due to the National Performance Agreements for Public Housing, signed by the Dutch government in 2022 with several stakeholders, including the Dutch Association of Housing Corporations (Aedes) and the Association of Dutch Municipalities (VNG). The agreements envision ending the social housing landlord levy if 75,000 tenants benefit from insulation and renovation activities, and 50,000 households are made natural gas-free annually until 2030[149].
- National Insulation Programme: The national insulation programme intends to insulate 2.5 million homes by 2030 through both an area-based and individual approach (with an emphasis on phasing out poor energy labels E, F, G) [150].
    - Not realistic to achieve as it requires a deep renovation rate of around 5%. Based on current measures and historical trends, this is difficult to achieve unless the renovation measures revolve around shallow renovations with low energy savings expected.
- Hybrid heat pump programme: This programme, introduced in 2022, aims to standardise hybrid heat pumps as the new norm for heating homes when installing a new heating

[146] Decarbonising Homes in Cities in the Netherlands: A Neighbourhood Approach

[147] Climate policy | Climate change | Government.nl

[148] Long Term Renovation Strategy - Netherlands

[149] Rijksoverheid (2022), Beleidsprogramma versnelling verduurzaming gebouwde omgeving, Beleidsprogramma versnelling verduurzaming gebouwde omgeving | Rapport | Rijksoverheid.nl

[150] Rijksoverheid (2022), Beleidsprogramma versnelling verduurzaming gebouwde omgeving, Beleidsprogramma versnelling verduurzaming gebouwde omgeving | Rapport | Rijksoverheid.nl

system or replacing existing ones from 2026 onwards. However, this was recently abolished and will no longer be a mandatory requirement. The programme aimed to install around one million heat pumps by 2030[151].

- Increased use of sustainable sources / fuels: in the Beleidsprogramma versnelling verduurzaming gebouwde omgeving (2022) programme, the Dutch government intends to pump around 1.6 billion m3 of green gas into the heating networks, resulting in a reduction of 2.9 MtCO2e emissions by 2030[152].
- Legal requirement of the phasing out of the worst energy labels (E, F, G) as of 1 January 2030, for the rental sector and is not applicable to the purchase sector[153].
- As of July 2018, new buildings in principle are banned from being heated with natural gas and would have to be heated by sustainable sources[154]. This has seen an increasing compliance rate, with 87% of new buildings in 2020 free of natural gas.
- Increased renovation rates up to 200,000 by 2030 and further accelerated increase beyond 2030 is needed to achieve the required decarbonisation targets[155].
- As of **January 1, 2023**, the Netherlands implemented a **0% VAT rate** on the supply and installation of solar panels when installed on or near residential properties. This measure aims to simplify the process for homeowners and encourage the adoption of renewable energy sources[156].
- The **Dutch National Heat Fund** (Nationaal Warmtefonds) is a government-backed financial initiative aimed at supporting homeowners, housing associations and schools in making energy-efficient renovations. It provides **affordable loans** to finance sustainable home improvements, such as insulation, heat pumps, solar panels, and other energy-saving measures[157].

Recently, due to political changes, several drawbacks have emerged that may hinder decarbonisation efforts. These include a reduction in subsidies for sustainability measures, lower energy taxes, and less stringent sustainability rules for new buildings. In addition, the above-mentioned mandatory installations of hybrid heat pumps starting from 2026 has been abolished.

Additional drawbacks include the termination of the net metering scheme (salderingsregeling) as of January 2027 for small scale solar panel users. This means that the ability to offset fed-in electricity against consumed electricity will cease. Instead, energy suppliers will offer **reasonable compensation** for the electricity fed back into the grid[158].

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[151] Rijksoverheid (2022), Beleidsprogramma versnelling verduurzaming gebouwde omgeving, Beleidsprogramma versnelling verduurzaming gebouwde omgeving | Rapport | Rijksoverheid.nl

[152] Rijksoverheid (2022), Beleidsprogramma versnelling verduurzaming gebouwde omgeving, Beleidsprogramma versnelling verduurzaming gebouwde omgeving | Rapport | Rijksoverheid.nl

[153] IBO (2023), Scherpe doelen, scherpe keuzes: IBO aanvullend normerend en beprijzend nationaal klimaatbeleid voor 2030 en 2050, Scherpe doelen, scherpe keuzes: IBO aanvullend normerend en beprijzend nationaal klimaatbeleid voor 2030 en 2050 | Rapport | Rijksoverheid.nl

[154] EHI (2024), Heating Market Report 2023, European Heating Industry: Heating Market Report 2023

[155] Long Term Renovation Strategy - Netherlands

[156] From 2023 in The Netherlands, solar panels installed on or near your home are subject to a 0% VAT rate. - Ampowr

[157] The Dutch National Heat Fund – Nationaal Warmtefonds

[158] Netting scheme solar panels ends per 2027 | Business.gov.nl

Parameters implemented measures in the model

Assessment of historical trends along with current policies and measures allowed the identification of specific parameters for each of the modelled scenarios as shown in Table 13.

Table 13: Parameters for modelled scenarios – Netherlands

Scenario	Parameter	Description
BAU	**Renovation rate**	Historically, the annual renovation rate in the Netherlands is estimated to be around the EU average of 1%, which is still below the threshold of achieving any of the decarbonisation targets. This is assumed to be the case in the BAU scenario, with a slight increase to 1.4% from 2030 onwards to account for the natural uptick of renovations.
	Renovation depth	Historically, shallow non-energy related renovations have dominated the Dutch buildings sector. For future BAU scenario projections, an increased uptake of moderate and deep renovations is assumed with most annual renovations allocated for medium renovations achieving an average of 50-60% energy savings.
	Heating systems exchange	Historically, natural gas condensing boilers were the most sold technology for heating purposes. For future BAU scenario projections, the following was assumed: • **New buildings:** complete phase-out of natural gas systems as a result of the effective regulatory bans on installations of gas systems in new buildings. An increased share of district heating, biomass for SFH and hybrid and electric heat pumps. (following stock and sales development trends) • **Existing buildings:** continued but diminishing use of natural gas for system replacements until 2030, despite goals to phase out natural gas, mainly driven by the abolishment of mandatory heat pumps and reduced energy taxes. Other new systems include biomass, district heating, hybrid and electric heat pumps.
POLICY	**Renovation rate**	The renovation rate for the POLICY scenario is estimated to average 2.1%, accounting for the policy target of 200,000 annually renovated buildings, with slight buffer of 0.4% (instead of 2.5%) as a result of the lower uptake of renovations between 2021 and 2024 after the policy went into force. The renovation rate is assumed to fully materialise by 2030, assuming a linear increase between 2025 and 2030 to reflect a realistic growth.
	Renovation depth	An assumed increase uptake of moderate and deep renovations with most annual renovations allocated for medium renovations achieving an

		average of 50-60% energy savings. Shares of ZEB and ZEB-restricted renovations of the total annual renovations are assumed to be around 2-3% each by 2030 and 5-8% each by 2050.
	Heating systems exchange	• **New buildings:** complete phase-out of natural gas systems as a result of the effective regulatory bans on installations of gas systems in new buildings. A significant increase in the shares of hybrid and regular heat pumps compared to the BAU scenario. The remaining shares are allocated for district heating and biomass for SFH. • **Existing buildings:** complete phase-out of natural gas for system replacements by 2030. Increased shares of hybrid and regular heat pumps with biofuels. Focus on district heating connections accounting for the largest share in terms of new systems exchange to comply with the regulatory requirement of connecting 500,000 new district heating connections by 2030. Remaining shares are allocated for biomass and solar thermal systems for DHW generation.
NET-ZERO	**Renovation rate**	The renovation rate for the NET-ZERO scenario is estimated to average 3% accounting for a maximum realistically achievable renovation rate without exceeding the technical, social and financial feasibility limits for homeowners[159].
	Renovation depth	According to a comprehensive European study[160] on actual renovation rates and depth, it is estimated that about 5% of total floor area for Dutch residential buildings undergoes light, medium or deep renovations every year. Given the dominance of light renovations[161] across all EU countries, the study concluded that to improve overall renovation efficiency, buildings undergoing energy renovations must achieve greater renovation depth. At the same time, the total renovation capacity of the construction sector is limited, which means the annual renovated floor area will need

[159] This aligns with a Guidehouse study for the European Commission underpinning the EPBD impact assessment (see EPBD IA), where technical, social and economic parameters were assessed in depth for five European zones – East, West, North, North East South. The High-I and High-II scenarios (see EPBD IA) partially used renovation rates > 3% annually renovated floor area. However, for the actual EPBD proposal, it was concluded that maximum renovation rates of approx. 3%, as used in the 'Moderate' scenario, are a more realistic combination with average-depth whole-building renovations. This avoids over-burdening any of the assessed parameters (e.g. availability of supply chains, public acceptance, financial support, burden to the electricity grid). At the same time, it requires more effort in off-site decarbonisation to adhere to a net-zero emission pathway by 2050 than assumed in High-I and High-II scenarios. Due to the many boundary conditions determining the exact future renovation rates, even in the EPBD IA, no differentiation was applied between European zones.

[160] Hermelink, A., Schimschar, S., Esser, A., Dunne, A., Meeusen, T., Quaschning, S., Wegge, D., Offermann, M., John, A., Reiser, M., Pohl, A., & Grözinger, J. (2019). Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU: Final report. Research report prepared for European Commission, DG Energy. Ipsos; Guidehouse (formerly Navigant). https://op.europa.eu/en/publication-detail/-/publication/97d6a4ca-5847-11ea-8b81-01aa75ed71a1/language-en/format-PDF/source-119528141

[161] The study revealed a dominance of light renovations (defined to save between 3-30% of primary energy). However, the actual savings achieved were at the lower end of that range. Specifically, the EU average for primary energy savings was determined to be 13%, as shown in Table 4 in that study).

		to decrease as average renovation depths increase. This insight was later applied in the impact assessment preceding the European Commission proposal for EPBD 2024.
	Heating systems exchange [162]	• **New buildings:** complete phase-out of natural gas systems as a result of the effective regulatory bans on installations of gas systems in new buildings [163]. A significant increase in the shares of hybrid and regular heat pumps compared to the BAU scenario. For SFH up to 50% and 60% by 2030 and 2050, respectively, whereas for MFH up to 25% and 40% by 2030 and 2050 respectively. The remaining shares are allocated for district heating and biomass for SFH. • **Existing buildings:** complete phase-out of natural gas for system replacements well before 2030 [164]. Significantly increased shares of hybrid and regular heat pumps with biofuels. For SFH up to 40% and 60% by 2030 and 2050, respectively, whereas for MFH up to 25% and 40% by 2030 and 2050 respectively. Other new systems include biomass, district heating, and increased uptake of solar thermal systems for DHW generation. • Increased use of renewable fuels and a complete replacement of natural gas by 2040 from all existing systems[165]. • Accelerated decarbonisation rates for district heating achieving full decarbonisation by 2040[166]. District heating shares are being frontloaded to ensure compliance with regulatory targets of 500,000 new connections by 2030.

[162] The assumptions and changes here refer to the affected systems due to renovation activities and heating systems exchange rates and is not representative of the overall heating systems stock currently installed in the building stock. See Figure 3, section 2.3.1: *Heating systems stock* for heating systems stock development. The allocated shares are aligned with the proposed heat pumps uptake rate in the EPBD-IA for the western EU zone with modification to reflect the Dutch situation and current uptake of heat pumps.

[163] This is driven by several factors, including local regulatory bans and EPBD bans on financial incentives for standalone fossil fuel systems, making fossil fuels systems an unattractive solution. This also paves the way for all new buildings to meet the EPBD requirement that all new buildings be NZEB by 2030. In addition, the increasing use of heat pumps is ideal for new buildings to prevent high electricity loads and avoid overburdening the electricity grid.

[164] Setting 2030 as the cut-off year for new fossil-fuels systems replacements is driven by the need to fully decarbonise the buildings sector by 2050 and avoid lingering fossil-fuels systems, which typically have a lifetime up to 20 years, in the building stock.

[165] Assumptions are set as part of the authors interpretation of the FF55 2040 package. Refer to ch. 2.2.3 for further details.

[166] Assumptions are set as part of the authors interpretation of the FF55 2040 package. Refer to ch. 2.2.3 for further details.

5.2.4 Poland

Final energy consumption breakdown by type of end-use across the residential sector

In Poland, heating and DHW needs were responsible for around 81% of the total residential sector energy consumption, which underscores the role that heating and DHW play in decarbonising the residential sector. Figure 26 provides an overview of the final energy consumption by type of end-use in Poland.

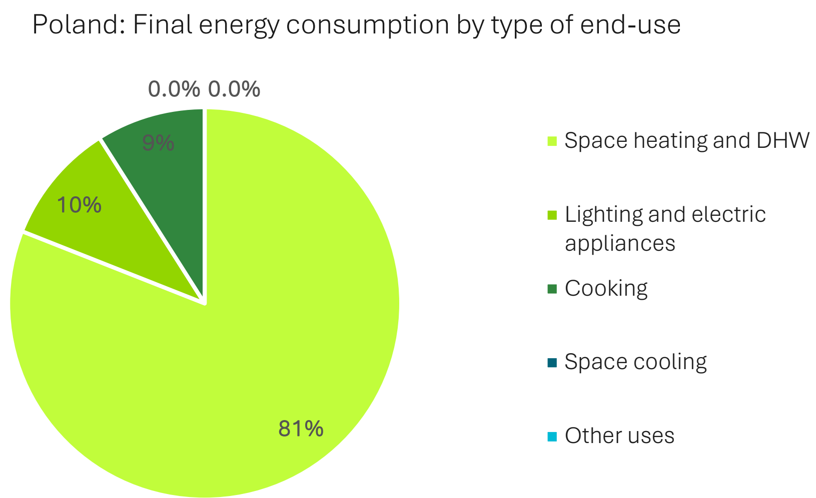

Figure 26: Share of final energy consumption by type of end-use – Poland
Adapted from EUROSTAT – Energy consumption in households[167]

Useful floor area distribution

Figure 27 illustrates the distribution of floor area in Poland's residential building sector. The residential building landscape in Poland spans a total useful floor area exceeding 988 million square meters[168]. Of this, SFHs constitute the majority, occupying 56% of the total area, reflecting a predominant historical preference for standalone residential spaces. LMFHs, which account for 35%, represent the second-largest segment, indicative of urban housing trends where higher-density residential options are common in cities. SMFHs make up the remaining 9%, typically offering lower-density alternatives to larger apartment complexes, potentially serving suburban or smaller urban markets.

[167] European Commission (2024), Energy consumption in households by type of end-use, Energy consumption in households
[168] EU Building Stock Observatory

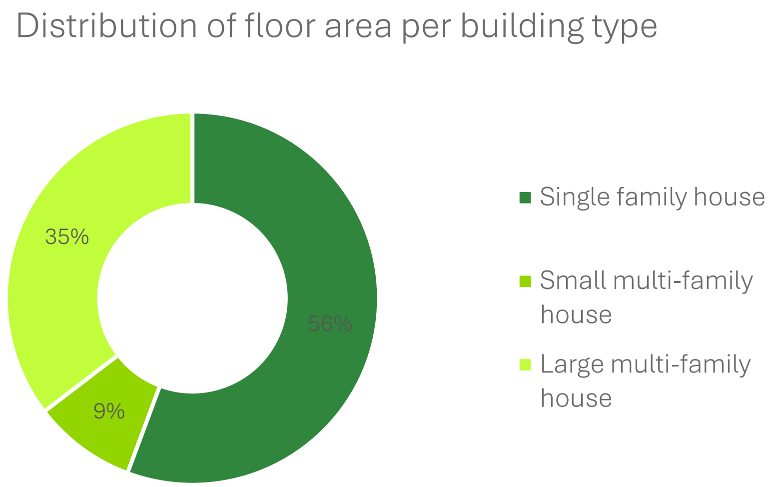

Figure 27: Distribution of floor area per building type in Poland
Adapted from EU Building Stock Observatory database[169]

Poland's housing stock grows at a construction rate of around 1.2% annually with a much lower demolition rate estimated at around 0.02%[170]. Despite the difference between the construction and demolition rates, Poland maintains one of the lowest housing availability rates in Europe and like the other assessed markets, it faces a significant housing shortage[171].

Figure 28 illustrates the distribution of building types by age group across Poland's current building stock, based on floor area. In terms of floor area, buildings constructed before 1945 make up a smaller share, with 16% for both SFH and LMFH and 14% for SMFH. The period from 1945 to 1994 represents the largest portion of the current building stock's floor area, with SFH accounting for 47%, LMFH for 43%, and SMFH remaining lower at 19%[172].

For buildings constructed from 1995 to 2020, the trend shifts significantly, as SMFH now dominates the distribution at 68% of the total floor area within this period. Meanwhile, SFH covers 38% of the floor area, and LMFH remains close at 41%[173].

[169] EU Building Stock Observatory
[170] Based on the average construction and demolition rates over the past 10 years: Statistics Poland : Construction
[171] Housing policy Poland | Habitat For Humanity
[172] EU Building Stock Observatory
[173] EU Building Stock Observatory

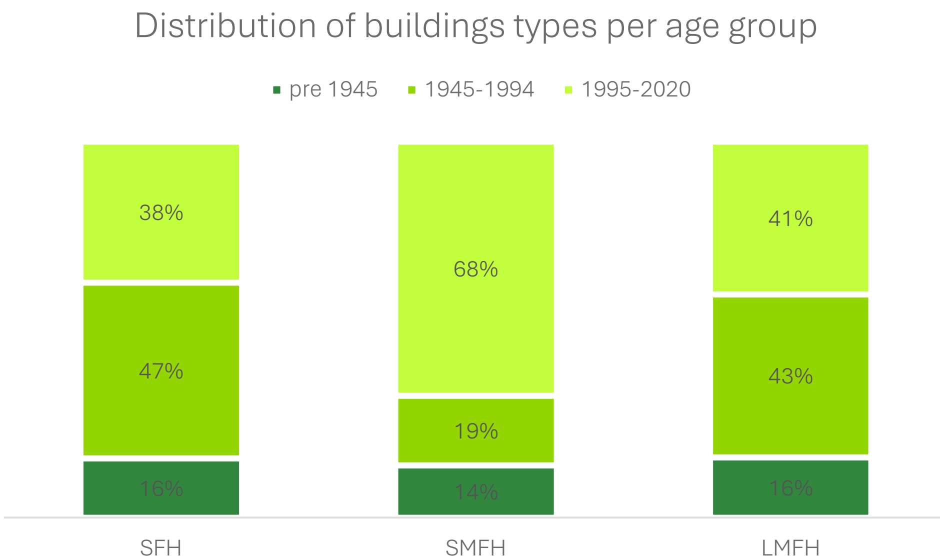

Figure 28: Distribution of building types per age group in Poland
Adapted from EU Building Stock Observatory database[174]

Current state of renovation

Figure 29 illustrates the current renovation status of the building stock, extrapolated from the EPBD-IA dataset[175], revealing a compelling distribution pattern across different types and eras of construction. Among SFHs, pre-1945 buildings show a relatively low renovation rate, with only 33% having been renovated, leaving 67% still in need of renovation. Post-1945, however, there is a significant increase in renovation efforts, particularly for buildings constructed between 1945 and 1994, where 64% have undergone some form of renovation, reducing the unrenovated share to 36%. In contrast, buildings constructed more recently, between 1995 and 2020, show limited renovation activity, with only 10% renovated. This likely reflects that newer constructions have yet to require extensive refurbishment or modernisation.

SMFHs exhibit a similar but slightly higher tendency for renovation across different age groups. For SMFHs, 37% of structures built before 1945 are renovated, compared to 63% unrenovated, suggesting reasonable improvement efforts relative to their age group. Notably, buildings constructed between 1945-1994 show the highest renovation levels, with 65% of them renovated. On the other hand, only 8% of SMFHs built between 1995 and 2020 have undergone renovation activities. This lower rate in newer buildings can be attributed to their construction with stricter standards and more efficient systems, reducing the immediate need for intervention.

[174] EU Building Stock Observatory

[175] Technical assistance for policy development and implementation on buildings policy and renovation – support for the ex-ante impact assessment and revision of Directive 2010/31/EU on energy performance of buildings.

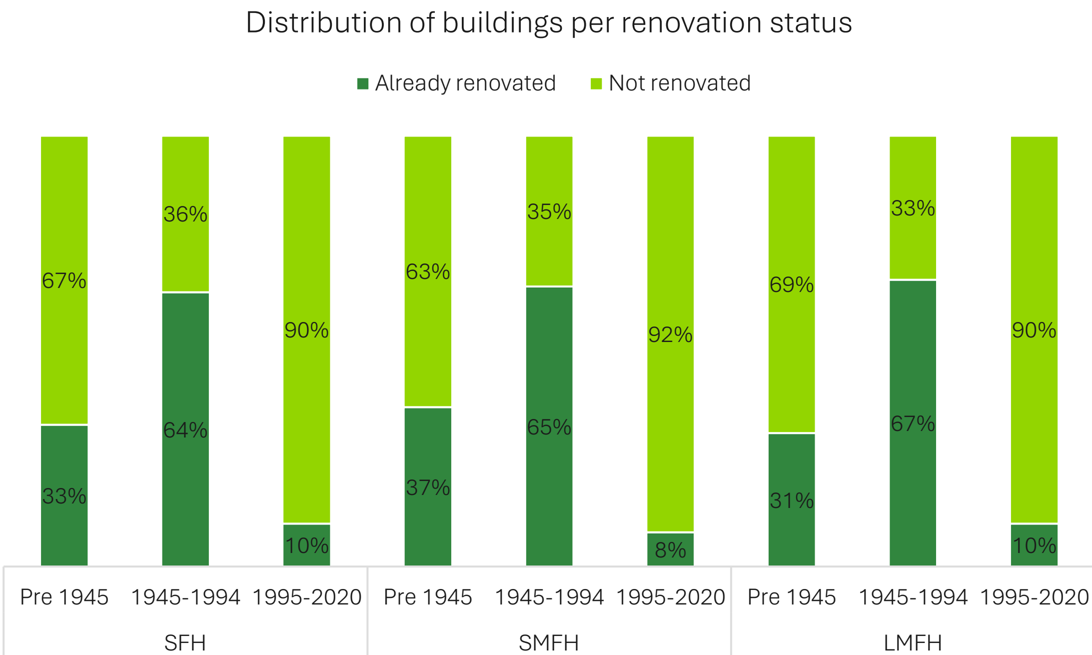

Figure 29: Distribution of buildings by renovation status in Poland

In LMFHs, renovation rates also reflect these trends, but with slight variation. Older LMFH buildings, specifically those pre-1945, have a renovation rate of 31%, slightly below that of SFHs and SMFHs in this category, with 69% still unrenovated. In the period from 1945 to 1994, renovation becomes more common, with 67% of LMFHs renovated. Buildings from 1995 to 2020 show minimal renovation activity at 10%. This can be attributed to contemporary design and construction standards that newer buildings meet, reducing the immediate necessity for renovation.

The distribution of renovated buildings across age groups has been estimated based on the renovation status distribution approximated in the EPBD Impact Assessment[176] project for the north-eastern Europe zone.

Heating systems distribution

Figure 30 shows the share of heating systems per building type and age group in Poland.

In Poland's building sector, heating systems show a significant dependency on fossil fuels, particularly coal, which remains prevalent across various building types and age groups. In older SFHs built before 1945, coal-based heating systems account for 34%, with district heating systems close behind at 29%. This coal dependency persists across other age categories, with SFHs from 1945-1994 still relying on coal for 22% of heating, and more modern SFHs (1995–2020) using 20% for their heating needs. District heating plays a central role in newer SFHs, particularly those built post-1995, reaching 31%. While gas heating has gradually increased

[176] Technical assistance for policy development and implementation on buildings policy and renovation – support for the ex-ante impact assessment and revision of Directive 2010/31/EU on energy performance of buildings.

from 21% in pre-1945 SFHs to 26% in more recent constructions, this shift has not been sufficient to significantly reduce coal reliance[177].

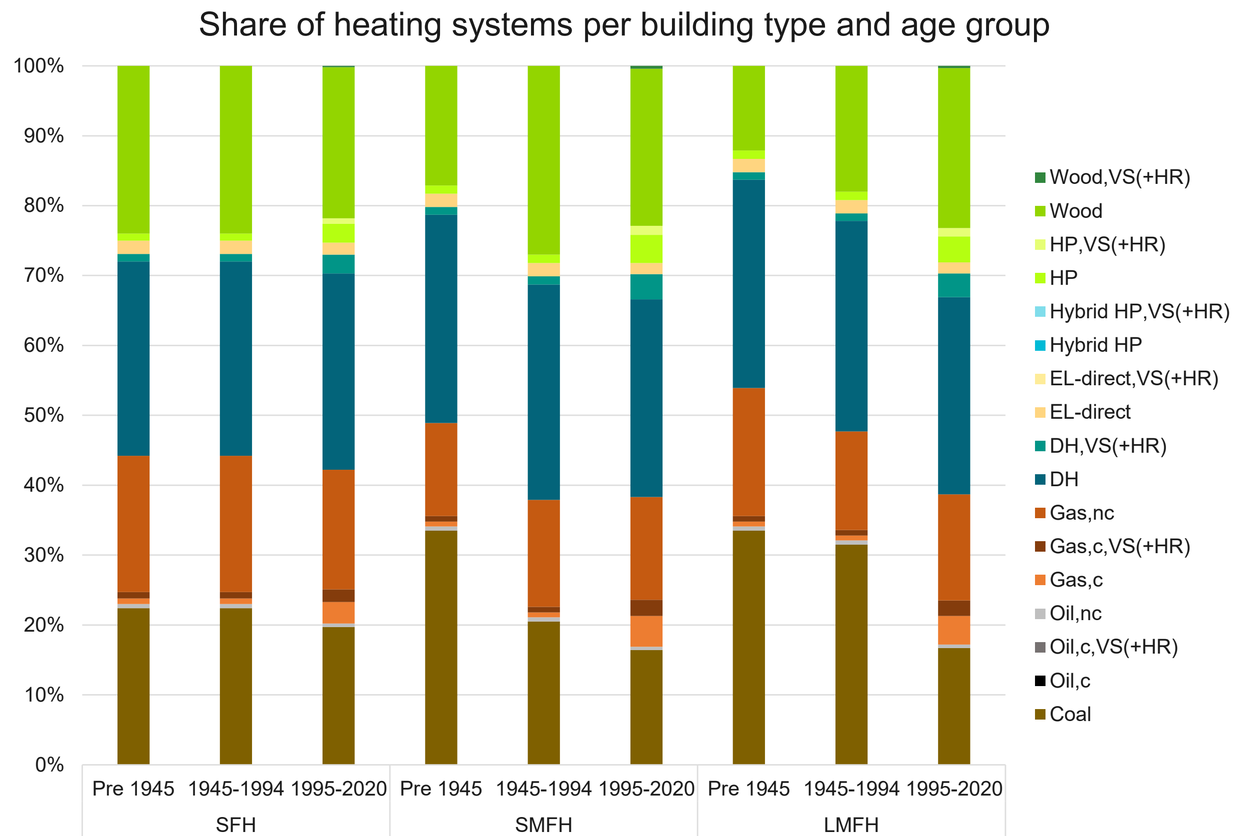

Figure 30: Share of heating systems per building type and age group in Poland
Adapted from EPBD-Impact Assessment Study and European Heating Industry

The heating landscape in multi-family houses, both small and large, also shows coal's pervasive role, especially in buildings from pre-1945. In these buildings, coal accounts for around 34% of heating systems in SMFHs and 34% in LMFHs, with district heating directly behind, at approximately 31%. Interestingly, while newer SMFH and LMFH constructions show some shift to less polluting options, such as gas (21% in SMFH and 22% in LMFH), the transition to more sustainable systems is slow, with coal use still substantial at 16% to 17% for these newer buildings[178].

While district heating provides an alternative and is widely used in both SMFH and LMFH sectors, particularly in newer constructions, the penetration of sustainable heating technologies like heat pumps remains low, accounting for only 1-5% across all categories. Direct electricity heating remains minimal, suggesting limited adoption of electric systems. Overall, Poland's high reliance on coal and limited penetration of alternative, low-carbon technologies indicate a pressing need for robust, high-level interventions to decarbonise the building sector. Such

[177] Technical assistance for policy development and implementation on buildings policy and renovation – support for the ex-ante impact assessment and revision of Directive 2010/31/EU on energy performance of buildings.

[178] Technical assistance for policy development and implementation on buildings policy and renovation – support for the ex-ante impact assessment and revision of Directive 2010/31/EU on energy performance of buildings.

efforts will be crucial in reducing fossil-fuel dependence and meeting future carbon-reduction targets.

Building stock energy performance

Building stock energy performance and final energy consumption are influenced by several factors, including building characteristics (age, insulation quality, size, construction material), energy systems and appliances, user behaviour, climate and weather, energy efficiency measures, and other external factors. Overall, the building stock in Poland is characterised by relatively high final energy consumption with buildings built pre-1945 having a final energy demand on average of around 330 kWh/m^{2}a. High energy consumption was observed towards the 1990s, with average final energy demand dropping to around 200 kWh/m^{2}a. From the 1990s onwards, this level continued to decrease, averaging 180 kWh/m^{2}a, and reaching its lowest levels of 145 kWh/m^{2}a post-2010[179].

From the perspective of this paper, buildings with a final energy consumption of 200 kWh/m^{2}a and above are considered worst-performing. Based on this criterion, most buildings in Poland can be considered worst-performing and in need of energy renovations.

The estimated distribution of Polish residential and public buildings by energy efficiency brackets are[180] 1% class: A, (1%) 4% class B, (4%) 24% class C, (24%) and over 70% class D and below. (31%)., E (24%), F (14%), G (2%).

Policies and measures

The Polish household heating sector is dominated by district heating, which supplies over 40% of the total households in the market, making Poland one of the most developed systems in Europe[181]. Around 75% of the heat generation in district heating is supplied by coal, along with a heavy reliance on coal for individual heating systems across the building stock[182]. This significance leads to the conclusion that many decarbonisation efforts in Poland are being directed towards transforming district heating to meet the decarbonisation targets defined by the EU and Poland.

To achieve the EU's ambitious 'Fit for 55' goals, Poland needs to reduce building GHG emissions by 20% compared to 2015 levels[183]. The Energy Efficiency Act of 2016 (Journal of Laws 2021, item 2166) is the key Polish legislative act related to energy efficiency. Poland has introduced a set of targets and measures to decarbonise the residential sector as follows:

- Energy Policy of Poland until 2040 (EPP2040): Adopted in February 2021, EPP2040 outlines the nation's energy transformation strategy, emphasising the reduction of coal usage in the residential sector and the enhancement of air quality[184].
    - The policy sets a target of achieving at least a 23% share of renewable energy sources (RES) in gross final-energy consumption by 2030.

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179 EURAC: European Building Stock Analysis

180 European Union (2022), Long-Term Building Renovation Strategy, https://energy.ec.europa.eu/system/files/2022-06/PL%202020%20LTRS%20_%20EN%20version.pdf

181 NetZero energy - 42% of households in Poland use district heating

182 Solar Thermal World – Transforming the polish district heating sector

183 Energy efficiency in the polish residential building stock: A literature review

184 Polityka energetyczna Polski do 2040 r. - Ministerstwo Klimatu i Środowiska

- Phasing out coal by 2040: coal will no longer be used in individual heating systems, with a gradual shift toward renewable energy for heating.
- New buildings are required to meet stringent energy-efficiency standards, incorporating renewable energy technologies (such as solar panels or heat pumps) and improved insulation to reduce overall energy consumption.
- Focused push towards zero-emissions: By 2040, at least 50% of new installations will use zero-emission energy sources, significantly reducing GHG emissions from the residential sector.

- As part of Poland's National Energy and Climate Plan until 2030, there is a target to phase-out coal-based heating systems in new homes by 2029, with the goal of transitioning to cleaner, renewable sources of heating[185]. The goal is to achieve complete decarbonisation of the building sector by 2050, with intermediate targets of reducing energy consumption by 55% in existing residential buildings by 2030. Poland aims for a gradual phase-out of coal heating systems in residential areas, focusing on electrification and the use of renewables.
- By 2050, all new buildings are expected to meet carbon-neutral standards, including the shift from fossil fuel-based heating systems to renewable energy sources like solar and geothermal energy. Interim targets for 2030 include significant reductions in energy use across all new residential constructions.
- Law on Energy Performance of Buildings (amended): in 2023, Poland revised regulations ensuring that having an energy certificate for a building is mandatory, with failure to comply subject to a fine.
- Poland's renovation strategy aims to renovate 3.8% of its building stock annually from 2020 to 2030. This means about 236,000 buildings are scheduled for renovation each year during the first decade, with the annual number increasing to 271,000 between 2030 and 2040. The strategy aims for the renovation of 7.5 million buildings by 2050, of which 4.7 million will undergo deep renovations[186].
- Emission Standards for Solid Fuel Boilers: In 2017, Poland introduced regulations prohibiting the sale and installation of low-efficiency solid fuel boilers, commonly known as 'smoky boilers'. These standards mandate that new boilers meet at least Class 5 emission requirements, significantly reducing particulate matter and other pollutants[187].
- Regional Anti-Smog Resolutions: Various voivodeships (provinces) have enacted anti-smog resolutions imposing stricter regulations on heating systems:
  - Małopolskie Voivodeship: Implemented a ban on the use of coal and wood in household heating systems in Kraków, effective from September 2019. The resolution also sets deadlines for phasing out non-compliant heating devices in other areas[188].
  - Śląskie Voivodeship: Adopted regulations requiring the replacement of outdated solid fuel boilers by specific deadlines, with a complete ban on the use of non-compliant heating devices by 2027.

[185] Krajowy Plan w dziedzinie Energii i Klimatu - Ministerstwo Klimatu i Środowiska

[186] European Union (2022), Long-Term Building Renovation Strategy, https://energy.ec.europa.eu/system/files/2022-06/PL%202020%20LTRS%20_%20EN%20version.pdf

[187] District heating sector in numbers: latest URE report - News - Energy Regulatory Office

[188] The call for proposals for the 'District Heating'' programme is now open - Ministry of Climate and Environment - Gov.pl website

- Clean Air Programme (Program Czyste Powietrze)[189]: Launched in 2018, this nationwide initiative provides financial incentives for homeowners to replace old, inefficient heating systems with environmentally friendly alternatives, such as gas boilers, heat pumps, and connections to district heating networks. The programme also supports thermal insulation improvements to enhance energy efficiency[190].

The impacts of financial measures are not quantified in the modelling and are used as indicative indicators of the availability of measures.

Parameters implemented in the model

Assessment of historical trends along with current policies and measures allowed the identification of specific parameters for each of the modelled scenarios as shown in Table 14.

Table 14: Parameters for modelled scenarios – Poland

Scenario	Parameter	Description
BAU	Renovation rate	Historically, Poland's annual renovation rate is estimated to be below the EU average of 1%, which is still below the threshold of achieving any of the decarbonisation targets. This is assumed to still be the case in the BAU scenario with a slight increase to 1.5% from 2030 onwards to account for the natural uptick of renovations.
	Renovation depth	Historically, shallow non-energy-related renovations have dominated the Polish buildings sector. For future BAU scenario projections, an increased uptake of moderate and deep renovations is assumed, with the majority of annual renovations allocated for medium renovations achieving an average of 50-60% energy savings.
	Heating systems exchange	Historically, coal boilers followed by gas non-condensing boilers were the most sold technology for heating purposes. For future BAU scenario projections, the following was assumed: • **New buildings:** complete phase-out of coal-based systems as of 2029. An increased share of natural-gas condensing boilers as an intermediate transition solution, followed by district heating, electric heat pumps and biomass. • **Existing buildings:** continued use of coal for system replacements until 2030 with natural gas gaining momentum as an intermediate transition solution. Other new systems include biomass, district heating, and electric heat pumps.
POLICY	Renovation rate	The renovation rate for the POLICY scenario is estimated to average of 2.0%, accounting for the policy target of an average of 260,000 annually renovated buildings. The renovation rate is assumed to fully materialise

[189] The Clean Air Programme has been suspended and is expected to return in spring 2025.
[190] Program 'Czyste Powietrze' - Do 136 200 zł na termomodernizację i wymianę źródeł ciepła

		by 2030 and, assuming a linear uptake between 2025 and 2030, to reflect a realistic increase.
	Renovation depth	An assumed increase uptake of moderate and deep renovations with most annual renovations allocated for medium renovations achieving an average of 50-60% energy savings. Shares of ZEB and ZEB-restricted renovations of the total annual renovations are assumed to be reach around 5% each by 2030 and 10% each by 2050.
	Heating systems exchange	• **New buildings:** complete phase-out of coal-based systems as of 2029. A minor increase in the share of natural-gas condensing boilers as an intermediate transition solution followed by a significant increase of electric heat pumps, district heating and moderate increase in biomass. • **Existing buildings:** soft phase-out of coal-based systems as of 2030. A minor increase in the share of natural-gas condensing boilers as an intermediate transition solution followed by significant increase of electric heat pumps, district heating and moderate increase in biomass.
NET-ZERO	**Renovation rate**	The renovation rate for the NET-ZERO scenario is estimated to average 3%, accounting for a maximum realistically achievable renovation rate, without exceeding the technical, social, and financial feasibility for homeowners[191].
	Renovation depth	According to a comprehensive European study[192] on actual renovation rates and depth, it is estimated that about 8.5% of total floor area for Polish residential buildings, undergoes light, medium or deep renovations every year. Given the dominance of light renovations[193] across all EU countries, the study concluded that to improve overall renovation efficiency, buildings undergoing energy renovations must achieve greater renovation depth. At the same time, the total renovation capacity of the construction sector is limited, which means the annual renovated floor

[191]This aligns with a Guidehouse study for the European Commission underpinning the EPBD impact assessment (see EPBD IA), where technical, social and economic parameters were assessed in depth for five European zones – East, West, North, North East South. The High-I and High-II scenarios (see EPBD IA) partially used renovation rates > 3% annually renovated floor area. However, for the actual EPBD proposal, it was concluded that maximum renovation rates of approx. 3%, as used in the 'Moderate' scenario, are a more realistic combination with average-depth whole-building renovations. This avoids over-burdening any of the assessed parameters (e.g. availability of supply chains, public acceptance, financial support, burden to the electricity grid). At the same time, it requires more effort in off-site decarbonisation to adhere to a net-zero emission pathway by 2050 than assumed in High-I and High-II scenarios. Due to the many boundary conditions determining the exact future renovation rates, even in the EPBD IA, no differentiation was applied between European zones.

[192] Hermelink, A., Schimschar, S., Esser, A., Dunne, A., Meeusen, T., Quaschning, S., Wegge, D., Offermann, M., John, A., Reiser, M., Pohl, A., & Grözinger, J. (2019). Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU: Final report. Research report prepared for European Commission, DG Energy. Ipsos; Guidehouse (formerly Navigant). https://op.europa.eu/en/publication-detail/-/publication/97d6a4ca-5847-11ea-8b81-01aa75ed71a1/language-en/format-PDF/source-119528141

[193] The study revealed a dominance of light renovations (defined to save between 3-30% of primary energy). However, the actual savings achieved were at the lower end of that range. Specifically, the EU average for primary energy savings was determined to be 13%, as shown in Table 4 in that study).

		area will need to decrease as average renovation depths increase. This insight was later applied in the impact assessment preceding the European Commission proposal for EPBD 2024.
	Heating systems exchange[194]	• **New buildings:** complete phase-out of coal-based systems, along with skipping natural gas systems as an intermediary transition solution[195]. A significant increase in the shares of electric and hybrid heat pumps with biofuels compared to the BAU scenario. For SFH up to 45% and 50% by 2030 and 2050, respectively, and for MFH up to 30% and 40% by 2030 and 2050 respectively. The remaining shares are allocated for district heating and biomass. • **Existing buildings:** complete phase-out of coal-based systems along with the minimal use of natural-gas systems as an intermediary transition solution until 2030[196]. Significantly increased shares of hybrid and regular heat pumps with biofuels. For SFH, up to 45% and 50% by 2030 and 2050, respectively, and for MFH, up to 25% and 40% by 2030 and 2050 respectively. Other new systems include biomass, district heating and increased uptake of solar thermal systems for DHW generation. • Increased use of renewable fuels and a complete replacement of natural gas by 2040 from all existing systems[197].

[194] The assumptions and changes here refer to the affected systems due to renovation activities and heating systems exchange rates, and are not representative of the overall heating systems stock currently installed in the building stock. See Figure 3, section 2.3.1: *Heating systems stock* for heating systems stock development. The allocated shares are aligned with the proposed heat pumps uptake rate in the EPBD-IA for the western EU zone, with modifications to reflect the Polish situation and current uptake of heat pumps.

[195] This is driven by several reasons, including local regulatory bans and EPBD bans on financial incentives for fossil fuel stand-alone systems, making fossil fuels systems an unattractive solution. This also paves the road for new buildings to align with the EPBD requirement that all new buildings be NZEB by 2030. Furthermore, the growing share of heat pumps is most suited for new buildings to avoid high electricity loads and prevent overburdening the electricity grid.

[196] Setting 2030 as the cut-off year for new fossil-fuel systems replacements is driven by the need to fully decarbonise the building sector by 2050 and avoid lingering fossil-fuel systems, which have a typical lifetime of up to 20 years, in the building stock. A special consideration for Poland includes the minimal use of natural-gas systems (<15%) in new installations as an interim solution. This approach aims to avoid an accelerated transition to heat pumps and electrification due to the current high emissions intensities of the electricity grid.

[197] Assumptions are set as part of the author's interpretation of the FF55 2040 package. Refer to ch. 2.2.3 for further details.

5.2.5 Spain

Final energy consumption breakdown by type of end-use across the residential sector

In Spain, heating and DHW needs were responsible for around 59% of the total residential sector energy consumption, which underscores the role their role in decarbonising the residential sector. Figure 31 provides an overview of the final energy consumption by type of end-use in Spain.

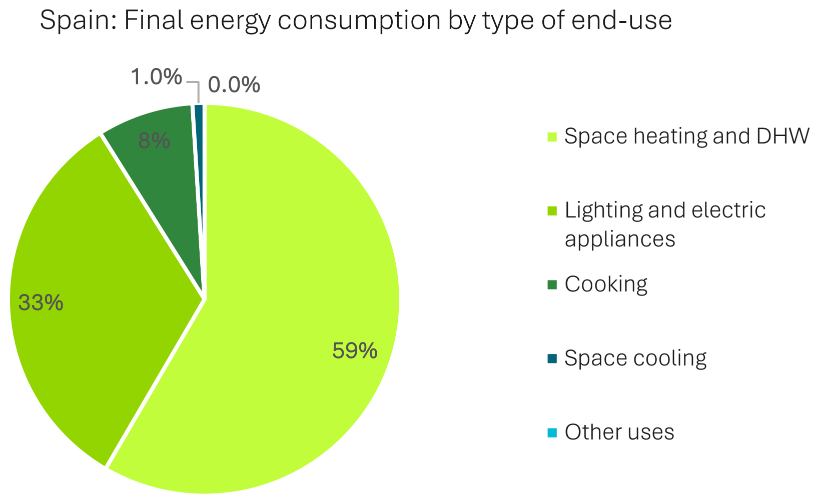


Figure 31: Share of final energy consumption by type of end-use – Spain
Adapted from EUROSTAT – Energy consumption in households[198]

Useful floor area distribution

The residential sector in Spain encompasses a total of 2.48 billion square meters of useful floor area. As illustrated in Figure 32, SFHs make up 43% of the total residential floor area. The remaining 57% are attributed to MFHs, with 44% LMFHs and around 13% for SMFHs, underscoring a strong preference for high-density residential structures, likely concentrated in urban regions[199].

[198] European Commission (2024), Energy consumption in households by type of end-use, Energy consumption in households
[199] EU Building Stock Observatory

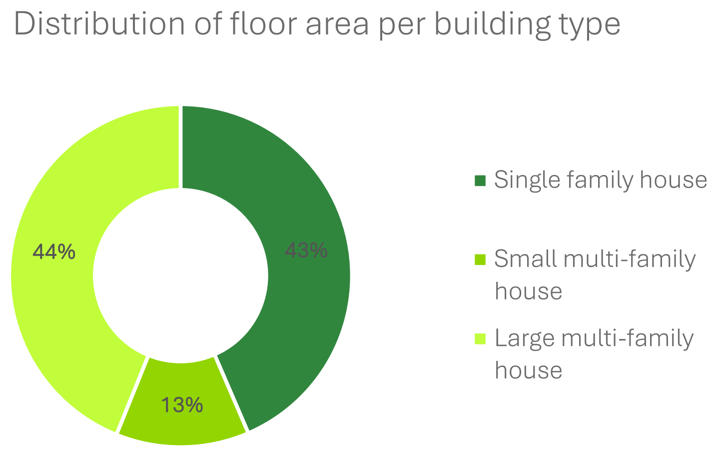


Figure 32: Distribution of useful floor area per building type in Spain
Adapted from EU Building Stock Observatory database[200]

Spain's new building rate in the residential sector is relatively modest, with just 0.3% of SFHs and 0.6% of MFHs being constructed each year. Demolition rates are similarly low, with 0.1% of SFHs and 0.2% of multi-family houses demolished annually[201]. Spain is facing a significant housing shortage with demand far exceeding the available supply. Current new annual constructions are estimated at around 90,000, in contrast to 600,000 pre the financial crisis in 2008[202].

Figure 33 highlights the distribution of building types per age group in Spain.

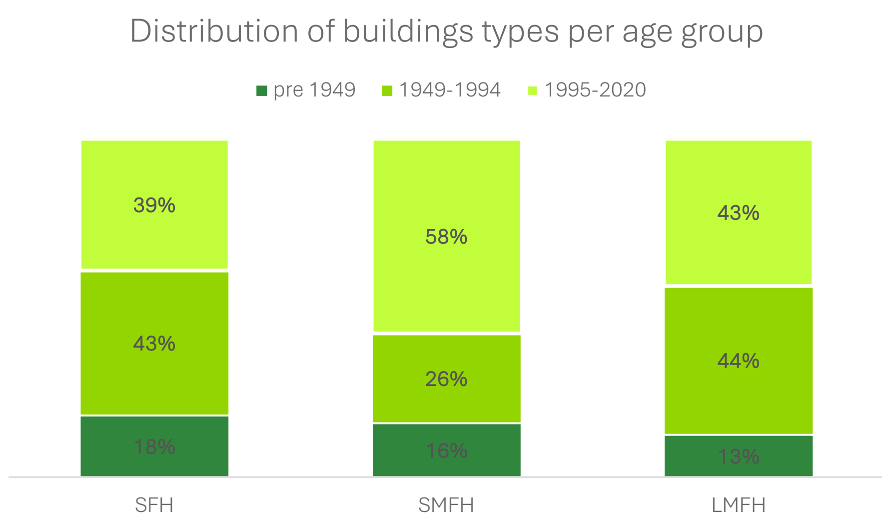


Figure 33: Distribution of building types per age group in Spain
Adapted from EU Building Stock Observatory database[203]

[200] EU Building Stock Observatory

[201] Technical assistance for policy development and implementation on buildings policy and renovation – support for the ex-ante impact assessment and revision of Directive 2010/31/EU on energy performance of buildings.

[202] The housing crisis in Spain

[203] EU Building Stock Observatory

Current state of renovation

Figure 34 illustrates the distribution of buildings by renovation status. The distribution of renovated buildings across age groups has been estimated based on the renovation status distribution approximated in the EPBD Impact Assessment[204] project for the southern Europe zone.

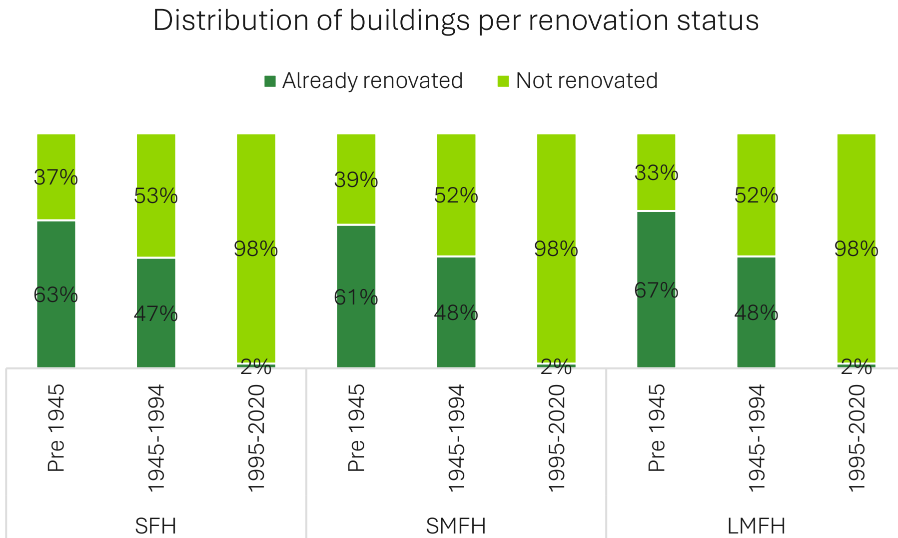


Figure 34: Distribution of buildings by renovation status in Spain

Heating systems distribution

Figure 35 illustrates the distribution of heating systems across building types and age groups in Spain, and highlights the significant dependency on non-renewable gas-based heating systems, especially within older structures. In SFHs, for instance, gas dominates as the primary heating source across all age groups, accounting for around 80% across all age groups. While alternative heating sources such as biomass and electricity are present in minor shares, they remain insufficient to shift the overall energy profile away from fossil fuels. In MFHs, a similar trend is observed. Gas accounts for more than 80% for SMFHs, and LMFHs across all age groups.

[204] Technical assistance for policy development and implementation on buildings policy and renovation – support for the ex-ante impact assessment and revision of Directive 2010/31/EU on energy performance of buildings.

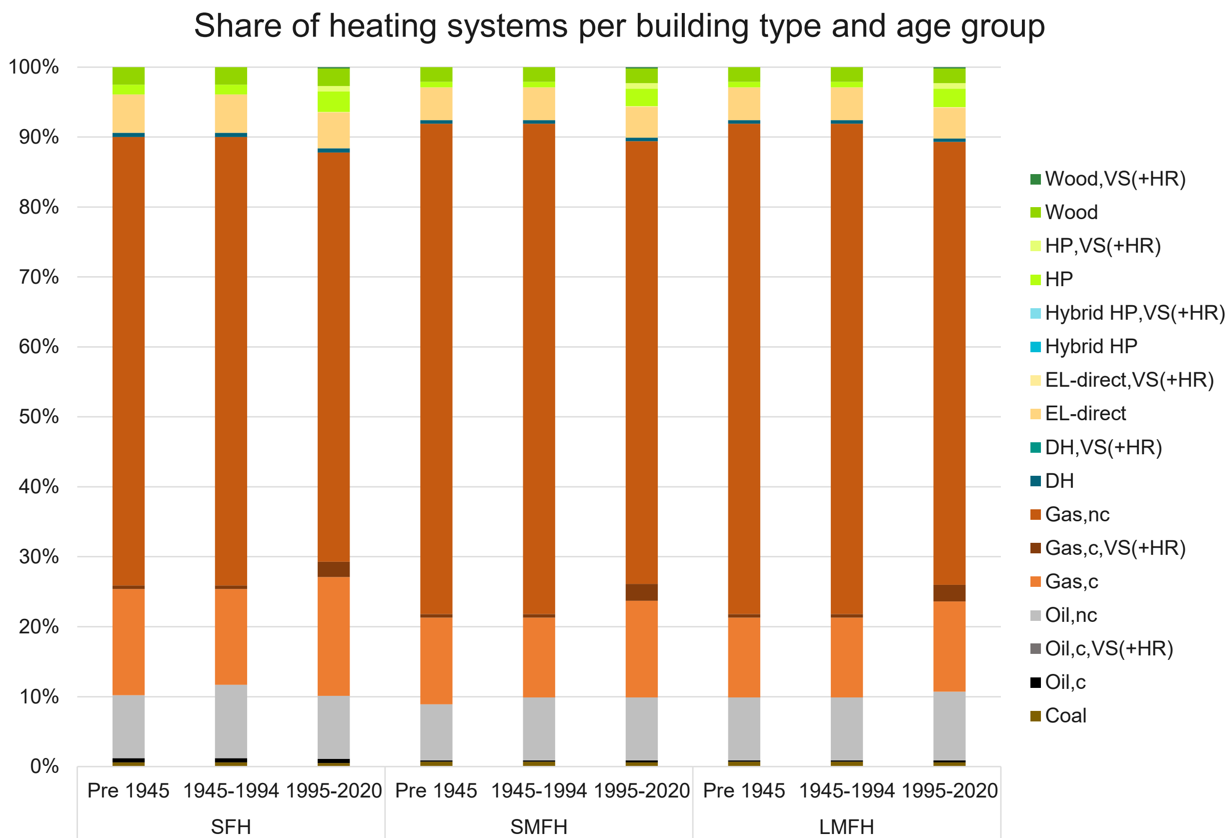


Figure 35: Share of heating systems per building type and age group in Spain
Adapted from EPBD-Impact Assessment Study and European Heating Industry

Across all building types, shares of renewable or low-carbon heating systems, such as heat pumps and biomass, are minimal. This low adoption rate of renewable heating technologies, combined with the consistent reliance on fossil fuel-based systems, underlines the non-renewable dependency within Spain's residential heating sector. Direct electric heating remains present across all types and age groups but remains below 6%, suggesting limited integration of electric heating alternatives despite their compatibility with renewable energy sources.

It is important to highlight that most of the building stock in Spain – around 90% – was constructed prior to the Technical Building Code, and around 60% was built without any energy efficiency regulations[205]. Despite the lower share of heating in the Spanish building stock, significant savings can still be achieved through deep renovation measures.

Building stock energy performance

Building stock energy performance and final energy consumption are influenced by several factors, including building characteristics (age, insulation quality, size, construction material), energy systems and appliances, user behaviour, climate and weather, energy efficiency measures and other external factors. Overall, the building stock in Spain has a lower final energy consumption compared to the markets assessed in this paper. This is primarily due to the reduced need for heating, which results from Spain's climate and weather conditions. Nonetheless, buildings constructed up to the 1980s show relatively high final energy

[205] The residential building sector in Spain

consumption, averaging around 130 kWh/m^2 annually. The final energy consumption levels drop to around 74 kWh/m^{2}a for buildings constructed post 2010.[206].

From the perspective of this paper, buildings with a final energy consumption of 200 kWh/m^{2}a and above are considered worst-performing. However, in the context of Spain, nearly all buildings need energy renovations due to the absence of energy performance standards in buildings constructed prior to 1980s. Despite the overall lower energy demand, the focus should be on the roughly five million highly energy-consuming properties in colder regions, which account for more than 80% of the total heating demand in Spain.

In terms of EPC distribution, homes labelled A, B and C account for slightly over 5% of the housing stock in Spain, while 9.6% have D certification.[207]

Policies and measures

A significant portion of Spain's building stock is outdated and inefficient, lacking proper insulation. The government aims to address this by promoting energy retrofitting, focusing on building envelopes, and heating systems, where 42% of household energy consumption is concentrated[208]. Therefore, Spain is pursuing a 'Modern, Competitive and Climate-Neutral Spanish Economy' by 2050, with a final energy consumption reduction target of 36% by 2050, compared to the 2020 level. To achieve that, Spain has implemented a comprehensive set of policies and measures to decarbonise its residential sector, aiming to enhance energy efficiency and reduce GHG emissions. Key initiatives include:

- National Energy and Climate Plan (PNIEC) 2023-2030: Spain's PNIEC outlines strategies to achieve a 32% reduction in GHG emissions by 2030 compared to 1990 levels[209].
  - The plan emphasises energy-efficiency improvements and the integration of renewable energy sources in residential buildings.
  - As part of the PNIEC, another programme for the rehabilitation of buildings hopes to retrofit 477.300 buildings for the whole period, from 2023-2030. The measures include work on thermal envelope and thermal insulation to improve efficiency, connection to efficient heat and cooling networks that allow the supply of heat, cold and hot water to the building from waste energy, energy renewables, and other efficient systems.
  - Overall, Spain plans to renovate 1.377 million homes by 2030, increasing the renovation rate compared to earlier targets (was 1.2 million before).
- LTRS Spain: The LTRS in Spain outlines several targets and goals that contribute to decarbonisation. Spain has adopted nearly zero-emission buildings (NZEB) standards for new constructions, which include energy-efficient insulation, renewable energy installations like solar panels, and advanced heating/cooling systems. This means that all new buildings need to adhere to the NZEB standards by 2020-2030. By 2050, Spain aims for all new buildings to be carbon-neutral, achieving zero-energy consumption through renewable sources and improved energy performance standards[210].

[206] EURAC: European Building Stock Analysis

[207] National Integrated Energy and Climate Plan (PNIEC 2023-2030)

[208] Energy renovation of buildings in Spain and the EU

[209] Spain - Draft Updated NECP 2021-2030 - European Commission

[210] Long-term renovation strategies - Spain

In addition to the national level policies, regional policies also play a role, with tailored approaches and measures aimed at decarbonising their respective districts and cities. The main policies and measures targeting the decarbonisation of residential buildings decarbonisation in the three major regions, the Madrid region, Catalonia and Andalusia, are as follows:

Andalusia region:

- The Andalusian Energy Strategy 2020-2030 is this region's core policy for residential buildings. It aims to align with the EU's energy-efficiency targets that mandate a reduction of at least 11.7% of final energy consumption by 2030. It emphasises the renovation of existing residential buildings to improve energy performance, and promotes the integration of renewable energy sources, such as solar panels, in the housing sector[211].

- Several energy rehabilitation programmes that aim to enhance the energy efficiency of residential buildings through financial incentives and technical assistance for homeowners to implement energy-savings measures, including building renovations. Those include:
    - Energy Rehabilitation of Buildings Program (PREE)[212].
    - Aid Programme for Energy Rehabilitation Actions in Existing Buildings (PAREER II)[213].
    - Incentive Program for Sustainable Energy Development in Andalusia[214].

Catalonia region:

- Catalonia's Energy Outlook 2050 (PROENCAT 2050), approved in June 2023, serves as the roadmap for Catalonia's energy transition towards climate neutrality. It targets a 30.3% reduction in final energy consumption by 2050, with household sector consumption expected to decrease by 34.2%[215].

Madrid region:

- Madrid's Roadmap to Climate Neutrality by 2050, approved in March 2021, acts as a comprehensive plan targeting a 65% reduction in GHG emissions by 2030 compared to 1990 levels with the goal of achieving climate neutrality by 2050[216].

- Plan for Decarbonisation and Environmental Care: developed by the community of Madrid, this includes 58 measures to advance towards a carbon-neutral region. This plan focuses on enhancing energy efficiency in residential buildings, promoting the use of renewable energy, and encouraging sustainable construction practices[217].

The impacts of financial measures are not quantified in the modelling and are used as an indicative indicator to the availability of measures.

[211] Agencia Andaluza de la Energía - Energy Strategy
[212] IDAE - Programa PREE. Rehabilitación Energética de Edificios
[213] IDAE - Programa de ayudas para actuaciones de rehabilitación energética de edificios existentes
[214] Agencia Andaluza de la Energía - Programa para el Desarrollo Energético Sostenible de Andalucía
[215] Government of Catalan - Government approves roadmap for Catalonia
[216] Madrid roadmap climate neutrality
[217] Comunidad de Madrid Plan para la Descarbonización y cuidado del Medio Ambiente

Parameters implemented in the model

Assessment of historical trends, along with current policies and measures, allowed the identification of specific parameters for each of the modelled scenarios as shown in Table 15.

Table 15: Parameters for modelled scenarios – Spain

Scenario	Parameter	Description
BAU	**Renovation rate**	Historically, Spain's annual renovation rate is estimated to be below the EU average of 1%, which is still below the threshold of achieving any of the decarbonisation targets. This is assumed to still be the case in the BAU scenario with a slight increase to 1.3% from 2030 onwards to account for the natural uptick of renovations.
	Renovation depth	Historically, shallow non-energy related renovations have dominated the Spanish buildings sector. For future BAU scenario projections, an increased uptake of moderate and deep renovations is assumed, with most annual renovations allocated for medium renovations achieving an average of 50-60% energy savings.
	Heating systems exchange	Historically, natural-gas condensing boilers were the most sold technology for heating purposes. For future BAU scenario projections, the following was assumed: • **New buildings:** continued use of natural gas for system replacements until 2030 with a focus on condensing boilers as opposed to historical trends of non-condensing boilers. An increased share of district heating, biomass for SFH and electric heat pumps. Based on historical stock and sales development patterns. • **Existing buildings:** continued use of natural gas for system replacements until 2030 with a focus on condensing boilers as opposed to historical trends of non-condensing boilers. An increased share of district heating, biomass for SFH and electric heat pumps. Based on historical stock and sales development patterns.
POLICY	**Renovation rate**	The renovation rate for the POLICY scenario is estimated to average 2.2%, which is still significantly lower than the rate targeted in the renovation strategy. However, the number of measures, along with historical patterns, limit the renovation rate. This highlights the need to develop more concrete measures development to achieve higher annual renovation rates. The renovation rate is expected to fully materialise by 2030, with a linear uptake assumed between 2025 and 2030 to reflect a realistic increase.
	Renovation depth	An assumed increase uptake of moderate and deep renovations with most annual renovations allocated for medium renovations achieving an average of 50-60% energy savings. Shares of ZEB and ZEB-restricted

		renovations of the total annual renovations are assumed to reach around 5% each by 2030 and 10% each by 2050.
	Heating systems exchange	• **New buildings:** continued use of natural gas systems until 2030 at a slower pace than that of the BAU scenario. A significant increase in the shares of electric heat pumps compared to the BAU scenario. The remaining shares are allocated for district heating and biomass. • **Existing buildings:** complete phase-out of natural gas for system replacements by 2030. Significant increase in shares of electric heat pumps. Other new systems include biomass, district heating and an increased uptake of solar thermal systems for DHW generation.
NET-ZERO	**Renovation rate**	The renovation rate for the NET-ZERO scenario is estimated to average 3%, accounting for a maximum realistically achievable renovation rate without exceeding the technical, social and financial feasibility for homeowners[218].
	Renovation depth	According to a comprehensive European study[219] on actual renovation rates and depths, it is estimated that about 4% of total floor area for Spanish residential buildings, undergoes light, medium or deep renovations every year. Given the dominance of light renovations[220] across all EU countries, the study concluded that to improve overall renovation efficiency, buildings undergoing energy renovations must achieve greater renovation depth. At the same time, the total renovation capacity of the construction sector is limited, which means the annual renovated floor area will need to decrease as average renovation depths increase. This insight was later applied in the impact assessment preceding the European Commission proposal for EPBD 2024.

[218] This aligns with a Guidehouse study for the European Commission underpinning the EPBD impact assessment (see EPBD IA), where technical, social and economic parameters were assessed in depth for five European zones – East, West, North, North East South. The High-I and High-II scenarios (see EPBD IA) partially used renovation rates > 3% annually renovated floor area. However, for the actual EPBD proposal, it was concluded that maximum renovation rates of approx. 3%, as used in the 'Moderate' scenario, are a more realistic combination with average-depth whole-building renovations. This avoids over-burdening any of the assessed parameters (e.g. availability of supply chains, public acceptance, financial support, burden to the electricity grid). At the same time, it requires more effort in off-site decarbonisation to adhere to a net-zero emission pathway by 2050 than assumed in High-I and High-II scenarios. Due to the many boundary conditions determining the exact future renovation rates, even in the EPBD IA, no differentiation was applied between European zones.

[219] Hermelink, A., Schimschar, S., Esser, A., Dunne, A., Meeusen, T., Quaschning, S., Wegge, D., Offermann, M., John, A., Reiser, M., Pohl, A., & Grözinger, J. (2019). Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU: Final report. Research report prepared for European Commission, DG Energy. Ipsos; Guidehouse (formerly Navigant). https://op.europa.eu/en/publication-detail/-/publication/97d6a4ca-5847-11ea-8b81-01aa75ed71a1/language-en/format-PDF/source-119528141

[220] The study revealed a dominance of light renovations (defined to save between 3-30% of primary energy). However, the actual savings achieved were at the lower end of that range. Specifically, the EU average for primary energy savings was determined to be 13%, as shown in Table 4 in that study).

	Heating systems exchange[221]	• **New buildings:** complete phase-out of natural gas systems as of 2025 [222]. A significant increase in the shares of hybrid and regular heat pumps compared to the BAU scenario. For SFH up to 60% and 65% by 2030 and 2050, respectively, and for MFH, up to 40% and 50% by 2030 and 2050 respectively. The remaining shares are allocated for district heating and biomass for SFH. • **Existing buildings:** complete phase-out of natural gas for system replacements well before 2030 [223]. Significantly increased shares of hybrid and regular heat pumps with biofuels. For SFH, up to 50% and 60% by 2030 and 2050, respectively, and for MFH, up to 40% and 50% by 2030 and 2050 respectively. Other new systems include biomass, district heating and increased uptake of solar thermal systems for DHW generation. • Increased use of renewable fuels and a complete replacement of natural gas by 2040 from all existing systems[224]. • Accelerated decarbonisation of district heating achieving full decarbonisation by 2040 [225].

[221] The assumptions and changes here refer to the affected systems due to renovation activities and heating systems exchange rates, and are not representative of the overall heating systems stock currently installed in the building stock. See Figure 3, section 2.3.1: *Heating systems stock* for heating systems stock development. The allocated shares are aligned with the proposed heat pumps uptake rate in the EPBD-IA for the southern EU zone, with modifications to reflect the Spanish situation and current uptake of heat pumps.

[222] This is driven by several factors, including local regulatory bans and EPBD bans on financial incentives for fossil fuel stand-alone systems, making fossil fuel systems an unattractive solution. This also paves the road for new buildings to align with the EPBD requirement that all new buildings being NZEB by 2030. Furthermore, the growing shares of heat pumps is most suited for new buildings to avoid high electricity loads and prevent overburdening the electricity grid.

[223] Setting 2030 as the cut-off year for new fossil-fuel system replacements is driven by the need to fully decarbonise the building sector by 2050 and to avoid lingering fossil-fuel systems, which typically have a lifetime of up to 20 years, in the building stock.

[224] Assumptions are set as part of the author's interpretation of the FF55 2040 package. Refer to ch. 2.2.3 for further details.

[225] Assumptions are set as part of the author's interpretation of the FF55 2040 package. Refer to ch. 2.2.3 for further details.

5.3 Methodological description stakeholder analysis

Table 16: Drivers mapped to PESTLE approach

PESTLE	Driver	Pivotal stakeholder groups
Economic	Funding and investment capacity The level of financial support and capital investment available to implement decarbonisation measures (e.g. subsidies, grants, private investments), which enable the decarbonisation measures.	• Commercial banks • National governments • National banks and banking associations
Economic	Market dynamics The degree to which market forces create demand for low-carbon building technologies, influenced by policies, consumer awareness, pricing, and the availability of decarbonisation options (such as heat pumps or renewable energy generation) in the marketplace.	• Commercial banks • Installers • Manufacturers • National governments • Utilities
Technolo-gical	Innovation and technological The availability and advancement of technologies that support effective building decarbonisation, including innovations in renewable-energy integration, energy-efficient appliances or building elements, or more affordable solutions for building owners looking to decarbonise.	• Academic and research institutions • Developers • Energy service companies • Manufacturers
Social	Public and policy advocacy Extent of public support and advocacy for decarbonisation policies and behaviour to promote awareness, shape favourable (or unfavourable) opinions, and drive change that supports building decarbonisation. Also includes educating the public about the importance and benefits of energy-efficient buildings.	• Academic and research institutions • Media, think tanks • Building associations • Installers • Commercial banks
Political/ Legal	Regulation and Policy The strength and clarity of policies and regulations that mandate or encourage energy efficiency and emissions reductions in buildings, driving compliance and adoption of measures like more efficient building elements, renewable heating technologies and cleaner grid options.	• National Governments • Academic and Research Institutions • National Banks and Banking Associations • National governments

Table 17: Overview of key stakeholder groups

Commercial banks	Developers
Commercial banks that issue mortgages, potentially driving decarbonisation by offering green mortgage products or incentivising energy-efficient upgrades.	Entities responsible for constructing or renovating buildings, whose decisions impact the sustainability of properties entering mortgage portfolios.
Governments and regulators	Homeowners
National governments that establish nationwide regulations, incentives and policies aimed at decarbonising the building sector, directly affecting mortgage portfolios through mandated energy-efficiency standards.	Individual property owners whose participation in energy-efficient retrofits or improvements directly impacts the decarbonisation potential of mortgage portfolios. Institutional homeowners (including homeowner associations) are entities owning and managing large residential building stocks. These entities can incentivise energy-efficient retrofits or upgrades and thereby influence decarbonisation of large-scale residential building portfolios.
Housing associations	Installers
Industry organisations that advocate for sustainable building practices and influence policymaking relevant to energy-efficient buildings in mortgage portfolios	Professionals (individuals) who – on behalf of companies or sole traders – install specific energy-efficiency technologies as well as the maintenance and repair of these measures. By acting as trusted advisors, they guide homeowners through technical and financial aspect of energy saving measures.
Land developers and private landowners	Manufacturers
Entities responsible for constructing or renovating buildings, whose decisions impact the sustainability of properties entering mortgage portfolios.	Suppliers of energy-efficient building materials and technologies, thereby influencing the availability of sustainable options for properties with mortgage portfolios.
Media	National energy system operators
Media and think tanks are influential entities whose dissemination of information,	Transmission and distribution system operators (TSOs and DSOs) are responsible

research, and advocacy on energy-efficient practices and policies can shape public awareness and drive the adoption of decarbonisation measures across the building stock.	for the development and operation of infrastructure. The increased electrification of buildings and the rise in residential solar PV installations necessitate significant grid expansion efforts. These organisations manage and balance energy supply and demand, and their integration of renewable energy and support for electrification directly impact the decarbonisation of building energy consumption.
Tenants	Utilities
Building occupants whose engagement in energy-saving behaviours and support for energy-efficient upgrades contributes to the decarbonisation potential of residential and commercial properties.	Energy providers whose policies, renewable energy offerings, and collaboration on electrification and efficiency programmes play a pivotal role in advancing the decarbonisation of building stock. Additionally, they are critical in developing renewable energy projects and offering those products to the market.

5.4 Analysis criteria for measures' relative importance across the five markets

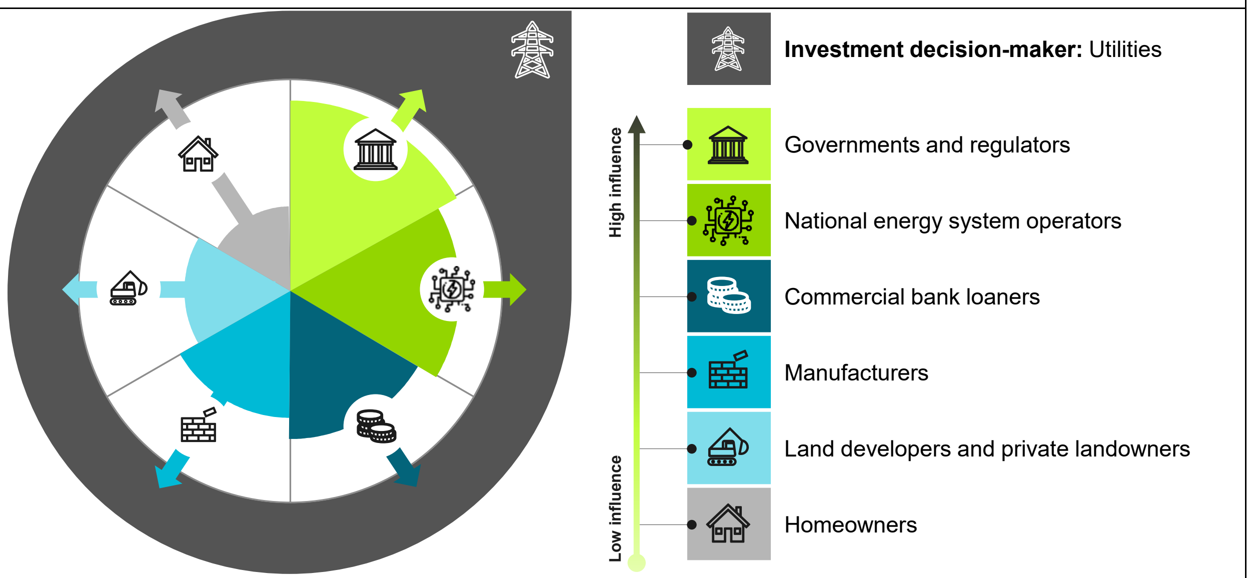
Table 18: Criteria and scale per analysis criterion

Measure	Criteria	Scale definition		
		Unit	Scale	Score
Greening the energy supply	Electricity grid mix	gCO_2e/kWh	x> 450	5
		gCO_2e/kWh	350 <x< 450	4
		gCO_2e/kWh	250 <x< 350	3
		gCO_2e/kWh	150 <x< 250	2
		gCO_2e/kWh	x< 250	1
	Readiness of existing heating systems for biofuels uptake and replacement of natural gas	%	x> 80%	5
		%	70% <x< 80%	4
		%	60% <x< 70%	3
		%	50% <x< 60%	2
		%	x< 50%	1
Deeper building envelope renovations	Theoretical energy demand intensity of worst performing buildings (pre-1945)	kWh/m^2a	x> 300	5
		kWh/m^2a	250 <x< 300	4
		kWh/m^2a	200 <x< 250	3
		kWh/m^2a	100 <x< 100	2
		kWh/m^2a	x< 100	1
	Share of buildings with high energy consumption larger than 200 kWh/m^2a in the residential building stock	%	x> 75%	5
		%	70% <x< 75%	4
		%	65% <x< 70%	3
		%	60% <x< 55%	2
		%	x< 55%	1
Heating systems upgrades and the potential for heat pumps uptake	Distribution of heating systems split between individual and centralised heating systems and the prevalence of district heating networks.	%	x> 90%	5
		%	70% <x< 80%	4
		%	60% <x< 70%	3
		%	50% <x< 60%	2
		%	x< 50%	1
Higher insulation standards and uptake of zero-emission buildings	Difference between current new build average and ZEB energy intensity levels	kWh/m^2a	x> 20	5
		kWh/m^2a	15 <x< 20	4
		kWh/m^2a	10 <x< 15	3
		kWh/m^2a	5 <x< 10	2
		kWh/m^2a	x< 5	1

5.5 Detailed assessment of stakeholder influence by technical measure

The following section illustrates the most influential stakeholder groups[226] in the investment decision-making process, viewed from the perspective of the primary investment decision-maker.[227] The decision-making process and the timelines for implementing these measures are influenced by various stakeholder groups. Through the activities outlined below, stakeholders can help foster a supportive environment for the final decision-maker.

Measure 1: Greening the energy supply



Investment decision-maker: Utilities

The primary decision-makers for power system decarbonisation investments are utilities. This is about large-scale renewable power generators connected to the energy grid (incl., e.g., PV, onshore and offshore wind, bio-CHP[228]).

Governments and regulators

Governments play a key role in accelerating grid decarbonisation by establishing policy and financial frameworks. By implementing supportive policies and providing incentives, they reduce investment risks and encourage the adoption of renewable energy technologies. In addition, they ensure that the benefits of grid decarbonisation are accessible to consumers while promoting a fair and sustainable energy market. They can take the following actions:

[226] All stakeholder groups included are considered influential but are presented in descending order of their impact on the decision-making process.
[227] This analysis is performed based on literature review and SME input.
[228] Bio-CHP: Combined Heat and Power

- Introduce financial incentives such as feed-in tariffs[229] and contracts for differences (CfDs)[230] to ensure stable revenue streams for renewable energy producers.
- Implement long-term energy policies that prioritise power-system decarbonisation and renewable energy development.
- Provide subsidies, tax credits, and grants to lower upfront costs for large-scale deployment of renewable electricity production, offshore wind and large-scale batteries. This also applies to solar PV installation for homeowners, including batteries and heat buffers.
- Streamline permitting processes to reduce administrative hurdles and accelerate project timelines.
- Design energy tariffs and provide clear price signals to encourage flexible energy use and network investment as well as to ensure homeowners are not overburdened by costs. This requires an overhaul of tariff methodologies to strike a balance between anticipating future infrastructure needs, accepting a higher degree of uncertainty that infrastructure assets might not be fully utilised, allowing for the early recovery of related costs, and managing affordability for consumers who bear the costs through network tariffs.
- Establish rules to manage smart-device integration and ensure savings are passed on to consumers.
- Protect low-income and vulnerable groups, ensuring equitable access to cheaper, cleaner energy.
- Secure a mandate to align regulatory efforts with net-zero goals.

In the EU context, the European Commission coordinates stakeholders to address the funding gap. Funding grid reinforcements and adaptations, estimated at half a trillion euros, face challenges like limited public resources, inflation, rising interest rates, and credit-rating risks for project promoters. Transmission and distribution operators are under pressure from unprecedented capital-expenditure demands, necessitating tailored financing solutions.

The European Commission aims to address these challenges by strengthening collaboration with investors, credit agencies, financial institutions, and system operators. Coordination with the EIB and alignment with the Wind Power Action Plan will ensure synergies across renewable energy projects, supporting a coherent and future-ready electricity system.[231]

National energy system operators

National energy system operators operationalise decarbonisation plans, ensuring the energy system evolves to meet net-zero ambitions while maintaining security and resilience. Also included in this stakeholder group are network operators, who ensure the reliable delivery of

[229] Guarantee fixed payments for renewable energy producers over a set period.

[230] (CfDs) stabilise revenues by compensating renewable energy producers for differences between a fixed strike price and market energy prices.

[231] EUR-Lex (2023), Grids, the missing link - An EU Action Plan for Grids, EUR-Lex - 52023DC0757 - EN - EUR-Lex

electricity, facilitate grid modernisation, and support the integration of renewable energy sources.[232] They can take the following actions[233]:

- National energy system operators:
  - Continuously manage energy generation and consumption to ensure a stable and efficient energy system.
  - Safeguard the electricity supply by preventing disruptions and addressing potential vulnerabilities in the grid.
  - Optimise the import and export of electricity to balance regional energy needs.
  - Manage system-wide responsibilities, such as integrating renewable energy and coordinating stakeholders (e.g. grid operators, energy producers) to align operations with decarbonisation objectives.

- Network operators can take the following actions:
  - Expand grid infrastructure for renewable energy integration and ensure sufficient capacity for renewable generators to connect to the grid.
  - Promote smart grids, network efficiency, and innovative technologies to improve the functioning of the electricity grids.
  - Participate in cross-sectoral initiatives and collaborate with technology providers to develop common technology specifications and improve visibility of grid project pipelines. This will facilitate investments in manufacturing capacity and secure supply chains.

Commercial banks

Commercial banks can play an active role by providing strategic funding for grid decarbonisation. Investments in advanced network planning optimise grid infrastructure for renewables, reducing operational risks and enhancing grid capacity. Additionally, loans for energy storage solutions empower utilities to store surplus renewable energy, supporting supply stability and improving project viability for renewable generators. Commercial banks can take the following actions:

- Provide funding for grid modernisation.
- Support investment in advanced network planning to optimise grid infrastructure for renewables, reducing operational risks and enhancing grid capacity.
- Offer loans to utilities and developers for energy storage solutions to enhance grid stability.
- Engage with governments to identify opportunities for public private financing.

Funding the necessary grid reinforcements and adaptations will require the mobilisation of vast resources, close to half a trillion, in a context where public resources are constrained and inflation and rising interest rates are hitting projects. For project promoters, there are also emerging issues with credit rating and access to capital. Grid operators, both at the

[232] The electricity network is managed by transmission and distribution network operators (TNOs and DNOs), who are responsible for the infrastructure that delivers electricity from generators through transmission and distribution network to homes and businesses. DNOs and TNOs play a key role in ensuring sufficient grid capacity and infrastructure is available to enable renewable energy generators to connect to the grid. Enabling sufficient storage capacity, network capacity flexibility and network planning capacity are crucial in this process.

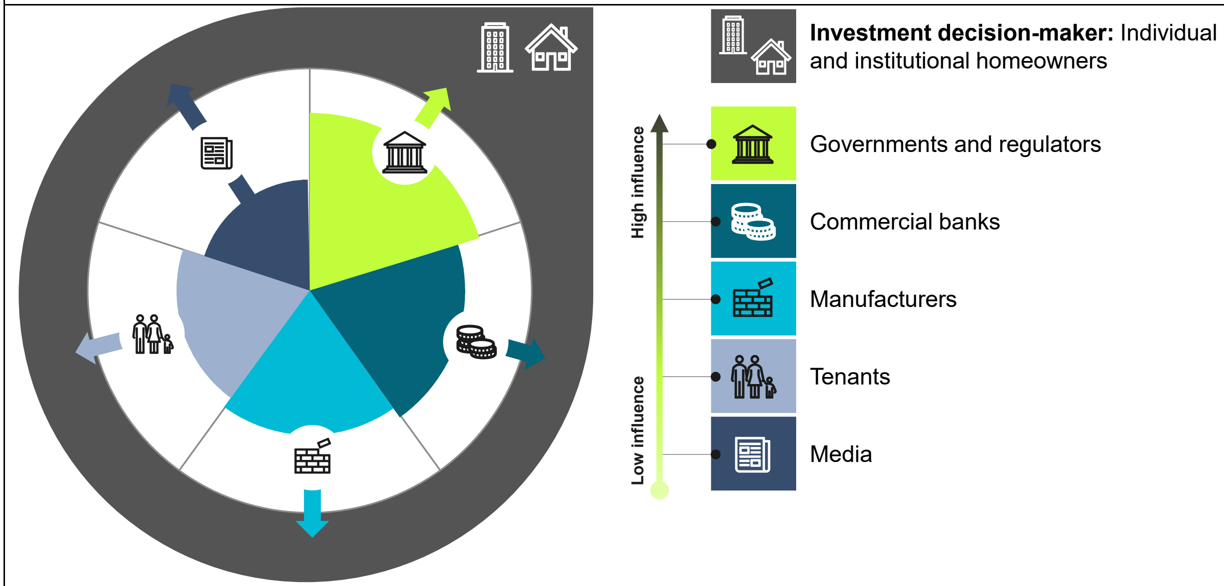
[233] Mission Statement | Netbeheerders

transmission and distribution levels, are faced with an unprecedented increase in the volume of capital expenditure. For example, the size and rapid extension of a company's investment programme may affect its credit rating, with negative consequences in access to finance. All of these require a new effort to identify tailormade financing products and instruments to support grid investments.	
	Manufacturers
Manufacturers influence renewable energy investment by leveraging global supply chains to obtain cost-competitive materials and/or elements to deliver affordable components and battery-storage solutions. By sourcing and producing cost-effective, high-quality components for solar panels and wind turbines, manufacturers lower barriers to entry for renewable projects. Access to scalable, competitively priced battery storage also enhances grid reliability, supporting the economic case for renewables. Manufacturers can take the following actions: • Source cost-competitive materials for renewable energy components (e.g. solar panels, wind turbines). • Invest in recycling, innovation, and research around substitutes for critical materials. • Decrease price volatility, by exploring opportunities for vertical integration and targeting long-term supply agreements to secure critical raw materials through industry alliances and partnerships. • Collaborate with utilities to gain clear demand signals on components through long-term target and volume commitments and proactively invest in capacity to support the energy transition. • Attract and retain talent through targeted reskilling programmes to tackle labour shortages.	
	Land developers and private landowners
In case of large renewable electricity projects (e.g. large-scale onshore wind projects), sufficient land area should be available. Land developers can play a pivotal role in securing this. Leasing or selling land for these projects helps secure optimal sites, particularly in high-resource locations, enabling renewable energy growth and supporting grid decarbonisation efforts. Land developers and private landowners can take the following action: • Facilitate renewable infrastructure expansion by providing land for solar and wind projects.	
	Homeowners
Individual homeowners also have a responsibility to contribute to local improvements that support this transition. By taking proactive steps, homeowners can complement broader supply-side initiatives. Key actions for homeowners include: • Installing rooftop solar panels or connecting to green energy providers to reduce reliance on non-renewable energy sources. • Upgrading home insulation and energy systems to reduce overall energy demand.	

Conclusion: Grid decarbonisation

Achieving power system decarbonisation requires coordinated efforts from diverse stakeholders, each playing a crucial role in supporting investment decision-makers – utilities and individual homeowners. Governments establish the enabling frameworks through policies, incentives, and equitable tariffs that encourage renewable energy adoption. Additionally, national energy system operators and network operators ensure the grid evolves to integrate renewable energy while maintaining resilience and reliability. Utilities expand renewable capacity through large-scale projects, while commercial banks provide critical funding solutions to overcome financial constraints. Manufacturers reduce barriers to entry by delivering cost-competitive components and fostering innovation. Finally, land developers and private landowners facilitate renewable infrastructure expansion by securing optimal sites for large-scale projects.

Measure 2: Deeper building envelope renovations (prioritise worst-performing buildings)



Investment decision-maker: Individual and institutional homeowners

The primary decision-makers for deeper building envelope renovations are individual or institutional homeowners, provided they have the required finance to invest in deep renovation). The decision-making process varies between individual and institutional homeowners. Contrary to the expectations of a significant gap where institutional homeowners tend to have much higher renovation rates due to policy mandates, the gap is actually narrow, as observed in an analysis of Dutch renovation rates from the Dutch EPC registry[234].

Government and regulators

The government implements regulations that incentivise deeper building envelope renovations. Through stringent energy-efficiency standards and performance codes, governments set benchmarks that encourage property owners to invest in upgrades. While homeowners are the investment decision-makers, governments, through the points outlined below, closely follow homeowners. They can take the following actions:

- Develop ambitious NBRPs under the EPBD, using MEPS as a baseline, to mandate and incentivise renovations, especially for poorly performing homes, and implement penalties for non-compliance where necessary.
- Set up the Building Passports[66]
- Establish voluntary Mortgage Portfolio Standards to standardise lenders' approaches to managing and decarbonising mortgage portfolios.

[234] E3S (2019), Analysing the Energy Efficiency Renovation Rates in the Dutch Residential Sector, Analysing the Energy Efficiency Renovation Rates in the Dutch Residential Sector

- Financial incentives, such as grants, subsidies, and loans with interest discounts, are essential for enabling these renovations by reducing upfront costs. They also should consequently steer the type of supported measures into a net-zero-compatible direction, by shaping eligibility criteria accordingly. While in Germany, e.g., wall insulation as an individual measure is supported with 15% of the investment cost, where the maximum investment cost is 30,000 EUR per dwelling unit, this increases to 20% and 60,000 EUR if that wall insulation would be part of a building renovation plan leading to a whole-building retrofit following the 'best possible' principle for each upgraded component.[235] Furthermore there is an additional 10% redemption grant for preferential loans when a worst performing building is renovated one-off to an 'efficient home' standard.[236] Financial incentives are also especially important for low-income or fuel-poor households, which often face barriers to accessing capital for energy-efficient retrofits. For example, in the Netherlands, the government offers financial support through programs like the National Energy Saving Fund, providing grants or loans with interest discounts to help lower-income households improve their homes' energy performance. For certain energy-saving measures, homeowners may be eligible for a grant or discounted loan.[237]
- Revision of regulations to enable those of lower socioeconomic status and retirees to qualify for renovation-specific loans, ensuring broader access to financing, offering additional tax benefits for energy-efficient renovations, and adjusting balance sheet requirements for 'green' or renovation loans. Consequently, making these products more attractive for banks to hold and encouraging greater financial sector participation in the decarbonisation effort.[238] Key drawback of the above are the processes related to the strict eligibility criteria to access funding; the administrative process required to prove eligibility can add complexity, potentially delaying or limiting the scope of building envelope renovations.

Commercial banks

Commercial banks are also an active stakeholder in the decision enablement of individual or institutional homeowners for deeper building envelope renovations, through debt financing tools like loans with interest discounts. Commercial banks can take the following actions:

- Develop pricing incentives and continuously refine them to make renovations more affordable and appealing.
- Support initiatives like the European Renovation Loan proposal to increase access to financing.
- Enhance and collaborate with renovation platforms and one-stop-shop concepts to streamline the renovation process in each market.
- Design conditional financing to encourage investments in deeper building renovations.

[235] Bundesamt für Wirtschaft und Ausfuhrkontrolle, Einzelmaßnahmen an der Gebäudehülle
[236] Worst Performing Building – die neue Gebäudekategorie
[237] Central government promotes energy savings | Renewable energy | Government.nl
[238] EIOPA (2024), Final Report on the Prudential Treatment of Sustainability Risks for Insurers, 'Final Report on the Prudential Treatment of Sustainability Risks for Insurers. EIOA recommends additional capital requirements for brown investments, applicable to insurance companies and pension funds.

One of the main challenges to overcome (jointly with governments) is that building owners may be reluctant to take on additional debt. Furthermore, as mentioned above, vulnerable groups may not be eligible for debt financing[239]. Community guidance (particularly in rural regions) and financial literacy can be provided by commercial banks on the case for building decarbonisation particularly when publicly available information on these products is relatively difficult to obtain[240].

Manufacturers

Manufacturers are critical for the provision of the components of deeper building envelope renovations, and play a key role within actors among the built environment. They can take the following actions:

- Avoiding hassle and reducing investment cost and installation time of building envelope renovations is a top priority for making them more attractive to homeowners and housing associations. This is the key driver of the 'Energiesprong' approach. Manufacturers can develop components which meet the requirements of pre-fabricated components. Pre.formance is a start-up of the Saint Gobain group, which is well known as a manufacturer of insulation materials. This start-up is dedicated to develop Energiesprong-compatible solutions, as already applied in a few promising demonstration projects together with other innovative component manufacturers aiming at integrated, pre-fabricated components not just including net-zero-compatible insulation but also appropriate technical building systems for heating, DHW and ventilation[241].
- Manufacturers can provide training and accreditation schemes for contractors in the use and installation of their products. These types of training programmes complement those offered at government-run, sponsored, or regulated institutions which are crucial for ensuring a sufficient supply of qualified and accredited installers for several energy efficiency measures such as roof/wall insulation and other energy-efficient technologies[242].

Tenants

Tenants are uniquely placed to influence deeper building envelope renovations, given that they are affected by the worst-performing buildings. Being affected first-hand by the potential impacts of renovations/no renovations means tenants can take the following actions:

- High demand from tenants for high-efficiency buildings means landlords may be more inclined to meet these demands. However, when housing shortages are severe[243],

[239] Energate (2023), Financing Typologies for Building Renovation, https://ieecp.org/wp-content/uploads/2023/07/BRIEF_Financing-Typologies-for-Building-Renovation.pdf

[240] MDBI (2023), Analyzing the Role of Banks in Providing Green Finance for Retail Customers: The Case of Germany, Analyzing the Role of Banks in Providing Green Finance for Retail Customers: The Case of Germany

[241] Reallabor Mönchengladbach, pre.formance

[242] Climate Action Tracker (2022), Decarbonising buildings Achieving zero carbon heating and cooling, Decarbonising Buildings - Achieving zero carbon heating and cooling - March 2022

[243] HOUSING FINANCE INTERNATIONAL (2021), Innovation in housing decarbonisation Germany, Innovation in housing decarbonisation: German

tenants lose bargaining power and are often forced to accept any housing available, regardless of preference or quality.

- The relationship that tenants have with their building owners is important. Inefficient properties that pose health risks to tenants may represent a liability for landlords as these buildings may lead to legal, financial and reputational consequences[244].

	Media

Organisations that disseminate information, shaping public and institutional attitudes toward building decarbonisation by raising awareness, promoting best practices and highlighting benefits of energy-efficient investments. They can take the following actions:

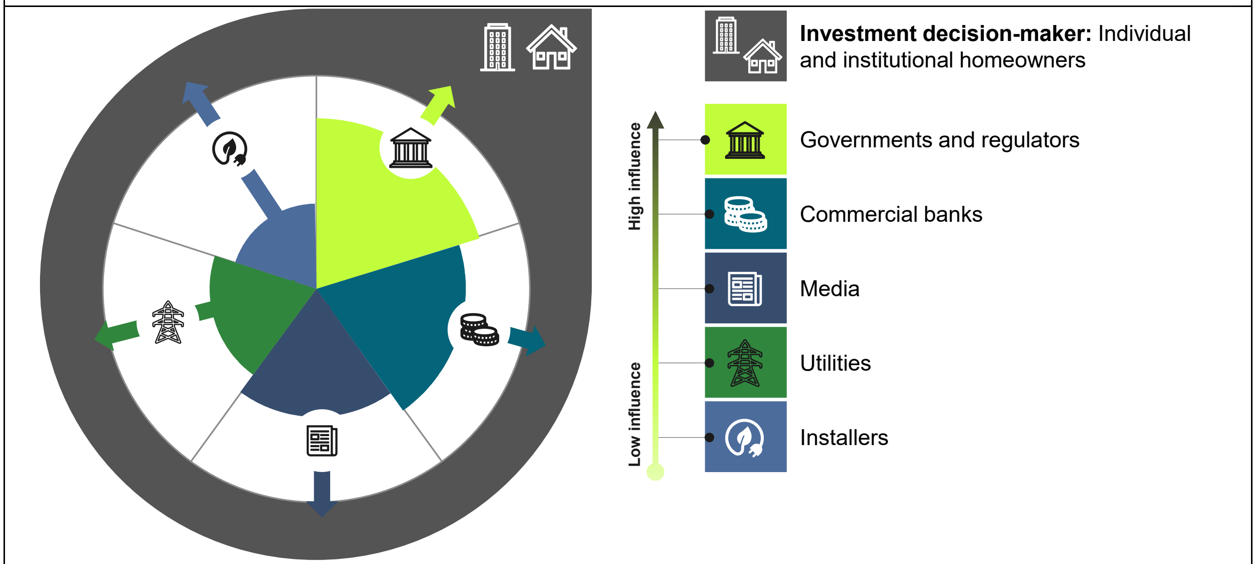
- Most values, beliefs, and even perceptions and preferences do not exist by themselves. They are shaped by the statements of others (what others know), making communication and trustworthiness essential factors in how people make decisions and consume information.
- Communicate about decarbonisation of buildings based on statistically based facts, rather than on exceptions, and connect more with experts to get things right.

Conclusion: Deeper building envelope renovations

For individual or institutional homeowners to move ahead with deeper building envelope renovations, stakeholders must ensure an environment is in place to best facilitate these renovations. Governments, in alignment with EPBD, must enforce stringent standards and provide the financial incentives for homeowners. Private renovation finance, through commercial banks, can provide innovative debt financing to ensure capital is available for such renovations. Manufacturers are also crucial for renovations in existing dwellings, through the provision, and subsequent training on, their low-carbon technologies. Lastly, tenants are also an involved stakeholder, through the direct influence they can have on their homeowners.

[244] National Housing Federation (2021), Decarbonisation: a guide for housing associations, https://www.housing.org.uk/globalassets/files/climate-and-sustainability--energy-crisis/07085855-9cf8-456c-8099-9506a6839b5d.pdf

Measure 3: Heating system upgrade and the uptake of heat pumps



Investment decision-maker: Individual and institutional homeowners

The primary decision-makers for investing in heating system upgrades are individual or institutional homeowners.[245]

Governments

Governments are crucial in driving heating system decarbonisation through regulations, financial incentives, and policy frameworks that lower barriers for homeowners to adopt renewable heating technologies. By supporting innovation and market growth, they enable a transition to sustainable heating systems. Governments can:

- Enact regulations to phase-out fossil-fuel heating systems and mandate renewable energy use (e.g., 65% renewable heating mandate in Germany[246]).
- Offer tax incentives, subsidies, and training grants to lower costs and support installers (e.g., heat pump training incentives).
- Adjust energy pricing policies to favour electricity over gas, increasing the appeal of electric heating systems.

[245] Whether this is individual or institutional homeowners (e.g. housing associations) depends on their share in the residential housing market and therefore differs per market. ‘Belgium, Germany, Poland, and Spain, unlike the Netherlands, have traditionally been characterised by individual ownership and limited institutional investment in housing. However, institutional ownership is increasing rapidly across these markets, and is now seen as a key solution to address housing shortages.’

[246] For example, the EU has agreed to ban fossil-fuel boilers by 2040 and cut subsidies by 2025 as part of its fossil fuel phase-out. This has significant implications for homeowners who will need to look for more energy-efficient alternatives such as heat pumps. As of 2024, the German government requires new heating systems to use at least 65% renewable energy sources.

- Promote domestic industries through sustained funding for technology development and deployment (e.g., Sweden's heat-pump programs[247]).

Commercial banks

Commercial banks can play an active role by offering affordable financing options that make energy-efficient heating upgrades accessible, enhancing ROI and accelerating adoption. Commercial banks can:

- Provide conditional loans[248] with interest discounts to reduce upfront costs for homeowners.
- Design conditional financing to encourage investments in sustainable heating technologies.
- Align financing models to support rapid energy savings offsetting loan costs.

Media

The media – which for simplification here also includes think tanks and research institutions – can raise awareness, validate technologies, and provide data-driven insights that build confidence in sustainable heating solutions. These stakeholders can:

- Highlight financial and environmental benefits of energy-efficient heating systems to make them relatable and appealing to homeowners.
- Produce and disseminate research validating the performance and cost-effectiveness of technologies like heat pumps.
- Advocate for the resilience and long-term value of sustainable heating investments against energy price volatility.

Utilities

Utilities are essential for providing power for heat pumps whenever needed, which become increasingly important with the large uptake of heat pumps required for net-zero goals. Simultaneously, the transport sector is also electrifying more and more. Therefore, managing renewable generation capacity and matching the fluctuating generation with demand from

[247] A key example is the case of Sweden mainstreaming heat pumps. Sweden has shown a sustained commitment over numerous decades to supporting domestic heat pump manufacturers. A technology procurement program was launched in 1993 and was combined with investment subsidies, information campaigns, and evaluations of heat pump installations. Support for the growth of a local manufacturing industry has helped make Sweden a global leader in heat pump adoption and production. Consistent funding to subsidise heat pump uptake sent a clear signal to industry participants that investing in the development of the sector was less risky than it would have been otherwise.

[248] Green loans with interest discounts are financial products offered by institutions to incentivise decarbonisation measures, such as energy-efficient renovations. However, these loans are conditional - borrowers must meet specific sustainability criteria to maintain the discounted interest rate.

heat pumps is a priority for a cost-effective future energy system. To make this happen, utilities can:

- Extend their renewable generation capacities as much as possible, in line with expected future demand patterns resulting from ongoing electrification.
- Introduce dynamic or at least time-of-use tariffs to steer the demand in a way that avoids demand 'valleys' or 'peaks', as this saves both costly generation capacity and grid expansion.
- Enter the heat-pump market themselves, to act as a large-scale provider of demand flexibility, where heat pumps but also other electrical appliances can be virtually linked to 'flexibility fleets'. Octopus energy is a company moving in this direction. They recently started selling heat-pumps, which they integrate into their highly digitised Kraken platform to create and control flexibility.[249]

Installers

Finally, literature shows[250] that installers hold substantial sway over homeowners' choices, due to their role as trusted advisors. Installers influence homeowner decisions significantly as trusted advisors, guiding the adoption of energy-efficient heating systems. Installers can:

- Educate homeowners about the benefits and performance of sustainable heating options.
- Provide tailored recommendations for system design, brands, and specifications to align with decarbonisation goals.
- Upskill through training to offer installation services for advanced heating technologies (e.g., heat pumps).
- Acquire the skills needed to properly and convincingly educate their clients on appropriate solutions for decarbonising their home.

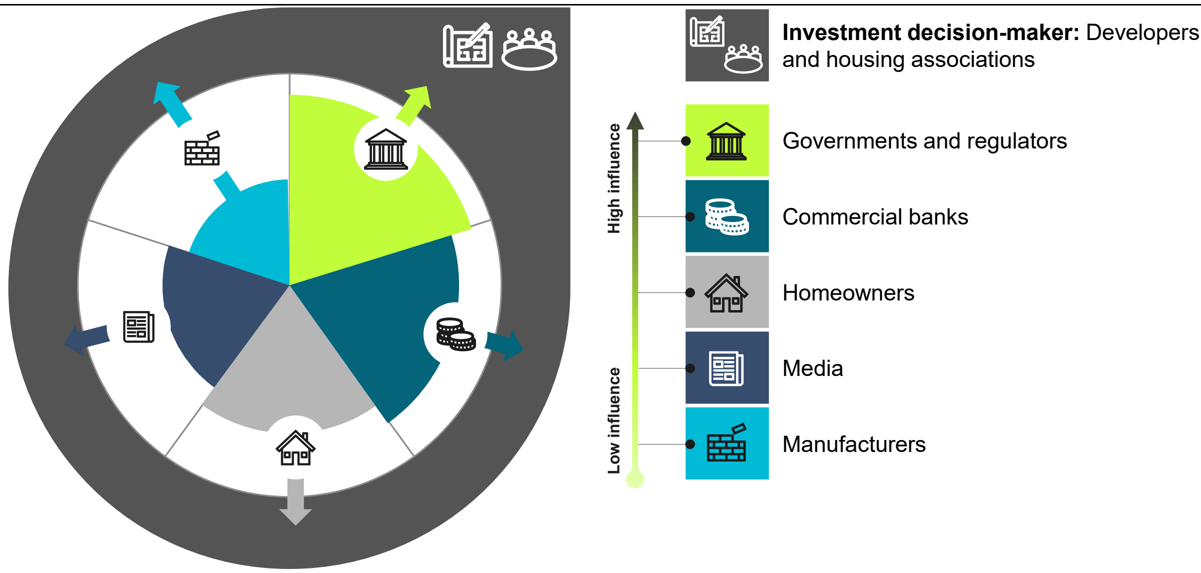
Conclusion: Heating system upgrade

To encourage homeowners to invest in heating-system upgrades, stakeholders need to create a supportive environment that reduces financial barriers and enhances the appeal of energy-efficient options. Governments should offer tax incentives, subsidies, and favourable policies, e.g., to change the relationship between electricity and gas prices, to make electric heating systems, like heat pumps, more attractive. Commercial banks can provide loans with interest discounts to lower the upfront cost, while media, think tanks, and researchers can promote the financial and environmental benefits, building homeowner confidence. Installers also play a crucial role as trusted advisors, influencing homeowners' decisions. These actions to be taken together among stakeholders, along with a favourable Total Cost of Ownership (TCO) ratio, will enable homeowners to make informed, financially viable decisions to go for the most appropriate set of decarbonisation measures.

[249] OctopusEnergy Kraken for Belgian households

[250] Maby, O. (2015), Installer Power. This study explores the significant influence of heating system installers on homeowners' decisions regarding energy efficiency upgrades, particularly in the UK.

Measure 4: Higher insulation standards and high-performance buildings (New buildings)



Investment decision-maker: Developers, individual homeowners and housing associations

The primary investment decision-maker for higher insulation standards and high-performance new builds are developers, individual homeowners, and housing associations (in case they have ownership of the buildings).

Governments and regulators

Governments influence the primary investment decision-makers for higher insulation standards primarily through regulation; by implementing EPBD and ensuring non-compliance is penalised. Governments also have considerable influence in shaping information provided to the primary decision-makers, and positive reinforcement of the benefits of implementing higher insulation standards must be prioritised.

The provision of subsidies and favourable incentives by national governments for higher insulation standards and high-performance buildings (regarding new buildings) are vital for increased uptake. Financial incentives are essential to achieving compliance as they alleviate the upfront cost burden and can provide tangible rewards for sustainable building practices.

Commercial banks

Commercial banks can encourage higher insulation standards and high-performance buildings (with regards to new buildings), through debt-financing tools like loans with interest discounts.

Commercial banks can provide discounted loans, with mechanisms to ensure that interest-rate discounts are maintained for loans associated with higher insulation standards and high-performance buildings. The overall aim is to increase renovation rates.

	Homeowners (individual and institutional, including homeowner associations)
Housing associations and homeowners are uniquely placed to deliver higher insulation standards and high-performance buildings (with regards to new buildings). Priority can be directed on delivering high-performance buildings and confronting potential emissions they can control by carrying out insulation improvements.	
	Media and researchers
The media pressures landlords to decarbonise by highlighting 'warm rent' (including energy costs) as a competitive factor, in contrast to 'cold rent', which only reflects base investment. This shift in focus encourages landlords to invest in energy-efficient upgrades to meet tenant demand for lower overall housing costs and stay competitive in the market. • By highlighting the financial and environmental benefits, media can make these topics more appealing to homeowners. Similarly, think tanks and researchers can validate the performance and cost-effectiveness of high-performance new builds, offering reliable data that builds homeowner confidence and underscores the resilience of such investments against fluctuating energy costs.	
	Manufacturers
Manufacturers are crucial to the primary investment decision-makers for higher insulation standards and high-performance new builds, given their role in the physical provision of solutions. While usually being rather removed from the final decision-making process, manufacturers are key to sourcing and delivering affordable, high-quality insulation. Providing access for various stakeholders to reliable and high-quality products is a key enabler for uptake amongst key investment decision-makers.	

Conclusion: Higher insulation standards and high-performance buildings

To support the decision making of developers and housing associations for higher insulation standards and high-performance residential real estate, coordinated actions by a variety of stakeholders are key. Governments should provide favourable financial incentives and ensure the financial feasibility of higher insulation standards in terms of total costs of ownership. This must be done in tandem with commercial banks who will be the key providers of private capital, enabling higher insulation standards to be met. The media and academic researchers have significant influence in shaping opinions on implementing higher insulation standards for housing associations and homeowners. Manufacturers should also focus on cost-effective production of high quality and low-cost insulation and support the wider building decarbonisation stakeholder network through trainings too. Overall, these stakeholders coming together can crucially impact the final decision making of developers and housing associations with regards to higher insulation standard implementation.

Box 5: The importance of Total costs of ownership (TCO[251]) for decision-making

The **total** cost and eventual payoff of allocating capital into making a 'high-performance building' has a strong influence on the Return on Investment (ROI)[252] and the total cost of ownership (TCO). TCO represents the total cost of acquiring, operating and maintaining an asset over its entire lifecycle. Homeowners often only focus on the upfront cost of an investment, but TCO includes ongoing expenses such as electricity costs. The relationship between electricity and gas prices in the market will determine whether TCO favours heat pumps or conventional (gas) heating systems. The same goes for the level of insulation leading to the lowest TCO: a (too) low energy price level, not reflecting the negative external impacts of (fossil) energy carrier (driven) use, will make lower levels of insulation look relatively better, although increasing the homeowner's vulnerability from energy price increases. ETS 2 will ensure that fossil energy carriers' prices will increase over time. This is another reason to make sure that sufficiently long assessment periods are taken for TCOs, to capture the full financial risk inherent in a continued increase of fossil-fuel prices.

Many stakeholders need to collaborate to make homeowners understand the potential financial risks associated with to a decision in favour of a low efficiency, low (initial) investment, fossil fuel-driven solution today.

[251] IEA (2022), Electric Vehicles: Total Cost of Ownership Tool, Electric Vehicles: Total Cost of Ownership Tool – Data Tools - IEA

[252] ROI focuses on the returns from an investment relative to its costs.

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