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EU CHALLENGES OF REDUCING FOSSIL FUEL USE IN BUILDINGS

THE ROLE OF BUILDING INSULATION AND LOW-CARBON HEATING SYSTEMS IN 2030 AND 2050

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Contents

Abstract

Energy scenarios that achieve a reduction of around 55% in greenhouse gas emissions by 2030, compared to 1990, endorse a rapid reduction of fossil fuel use in buildings in the EU. On average, these scenarios foresee a 60% reduction in oil and coal use and a 30% reduction in natural gas use in all buildings by 2030 compared to 2019. The main challenge is that these reductions in fossil fuel use and related greenhouse gas emissions must happen soon. Taking the energy scenarios together with the envelope renovation ambition in the Renovation Wave strategy, we have projected the necessary evolution of heating in buildings to meet our 2030 climate goals. Our analysis quantifies the steps needed to support the conclusion of the Renovation Wave strategy that fossil fuels will disappear from heating and cooling.

As mentioned in the Renovation Wave strategy, the EU will at least double the annual energy renovation rate of buildings by 2030. On the basis of our analysis, we conclude that envelope renovation rates may need to be differentiated based on the carbon intensity of heating systems. Before 2030, envelope renovation rates need to increase from around 1.3% currently to 2.0% for dwellings with non-fossil fuel heating, to 2.5% for dwellings currently using natural gas and to 3.3% for dwellings currently using oil and coal. After 2030, the projected envelope renovation rate could exceed 5% for dwellings currently using oil and coal.

If improvements are mainly to the thermal integrity of buildings, a reduction in heat demand of around 15% can be achieved by 2030. However, the reduction of oil use needs to be four times as high (-60%), and natural gas use twice as high (-30%), so envelope renovations need to be complemented with renovations that decarbonise heating systems, switching them away from fossil fuel.

Our study quantifies the extent of renovation needed for switching heating systems from fossil fuels to low-carbon alternatives. By 2030, at least 40 million existing dwellings should switch their fossil fuel boilers to low carbon heating alternatives, mostly heat pumps. In the period 2026-2030, our analysis shows that renovations would need to introduce low-carbon heating systems into an average 2.5% of stock every year. More than 3% of dwellings currently using natural gas would need to switch fuel, on average, every year from 2025. For dwellings currently using oil and coal, the switch rate would need to be more than 7%. For oil, the required rate is double the currently observed rate of replacement which includes today's like-with-like replacements (e.g. an old oil boiler replaced with a new oil boiler) and means that simply stopping the installation of new oil or coal heating devices would not be enough.

The extent of the decarbonisation required of heating systems is such that any additional envelope renovation for dwellings currently using fossil fuel also entails a switch to low-carbon heating systems. In fact, any renovations not involving a fuel switch to low-carbon heating should be avoided after around 2025 for dwellings currently using oil or coal, and soon after 2030 for dwellings using natural gas.

We provide important scientific evidence regarding the timing of phasing out new fossil fuel boilers in residential buildings and the impact if we delay action. Even when considering state-of-the-art technology, replacing fossil fuel boilers with newer fossil fuel boilers should be discontinued as soon as possible for oil and between 2025 and 2030 for natural gas. As a consequence, many more households should participate in energy or heating system renovations: around 30% of EU households by 2030 and more than 85% by 2050.

Acknowledgements

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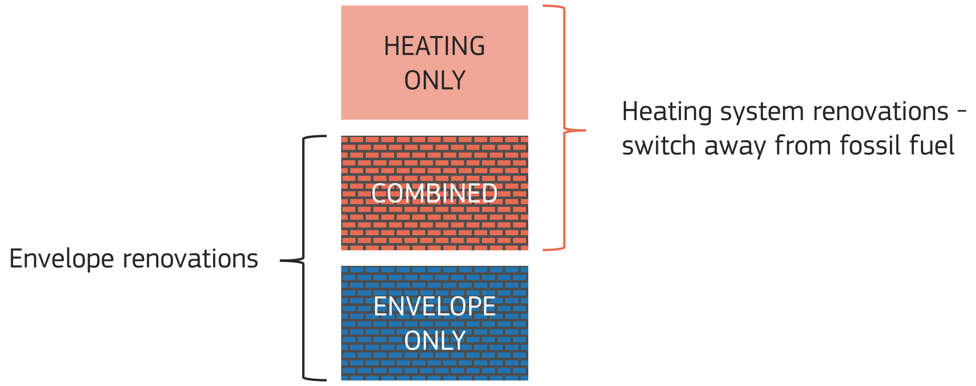
Executive summary

The aim of this report is to clarify some of the challenges related to reducing the consumption of fossil fuels in buildings. Large reductions of fossil fuel use are to happen soon and will require a fundamental change in how people think about renovations in buildings. EU policies already put the emphasis on spurring renewable energy sources in combination with measures that reduce energy demand with improvements to building envelopes. However, the decarbonisation of heat supply involves much more than adding renewable energy to buildings and will require switching our heating systems away from fossil fuels. This was an issue which received little attention before the EU declared its ambition to achieve climate neutrality. In other words, envelope renovations are mainstream, but renovations which switch to low-carbon heating are not.

Our study quantifies the extent of renovation needed for switching heating systems from fossil fuels to low-carbon alternatives, both in terms of technology scale-up and investment. Our starting point is the reduction of fossil fuel use averaged from a wide range of energy scenarios whose goal is a reduction of around 55% in greenhouse gas emissions by 2030 compared to 1990, and climate neutrality by 2050. After that, we create renovation scenarios that assume a gradual uptake of *envelope renovation rates* from around 1.3% today to a level of 2.5% of the dwelling stock (equivalent to a weighted annual reduction of demand for heating of 1.6%). Based on this, we analyse the *heating system renovations* necessary to reach the projected reductions of oil and gas use.

Figure 1 Definitions of renovations used in this report.



Source: JRC.

Policy context

The European Commission released its European Green Deal in November 2019, its proposal for a European Climate Law in March 2020, its 2030 Climate Target Plan in September 2020, its Renovation Wave initiative for the buildings sector in October 2020 and the first tranche of its Fit for 55 package containing the proposals required for delivering the European Green Deal in July 2021[1]. One of the actions proposed in July is to introduce carbon pricing for buildings by regulating fuel suppliers from 2026.

This report is relevant to the Renovation Wave strategy that will boost the energy renovation of buildings in the EU, and to the ongoing revision of the Energy Performance of Buildings Directive (EPBD) that will address the attainment of a highly energy-efficient and decarbonised building stock by 2050. The renovation scenarios in this report can also provide useful input to the ongoing revision of the Energy Efficiency Directive, and the Ecodesign and Energy Labelling regulations that set consistent, EU-wide sustainability requirements for space and water heating devices. It is also of relevance to the EU strategy on energy system integration by linking the buildings and power sectors.

[1] European Green Deal COM(2019) 640; European Climate Law COM(2020) 80 final; 2030 Climate Target Plan COM(2020) 562; Renovation Wave COM(2020) 662 and the proposals required for Delivering the European Green Deal (European Commission, 2021a).

This JRC report provides scientific evidence for:

- policymakers involved in rapidly increasing the renovation rate of the building envelope and the replacement of fossil fuel boilers with low-carbon heating alternatives;
- Member States taking action to decarbonise buildings;
- construction and heating sectors with an interest in assessing potential business opportunities.

Key conclusions

Conclusions are derived from literature survey and our own calculations. Conclusions related to energy flows and the reduction of fossil fuel use are based on results from a variety of energy scenario studies and are referenced as energy scenarios. Conclusions on renovations and heating systems are based on JRC estimates and are referenced as our analysis. In line with the aim of the Directives (EPBD, REDII, EED) and the Renovation wave to combine envelope improvements with increased use of renewable heating sources, we have reached the following key conclusions.

- For 2030, energy scenarios project reductions of oil and gas that are, respectively, four times and twice as high as that which can be reached with ENVELOPE ONLY renovations (which only improve the thermal integrity of buildings), even if we rapidly increase the annual envelope renovation rate from around 1.3% today to 2.5% of the stock. Though extremely important, envelope renovations fall short of achieving these reductions and need to be complemented with renovations that decarbonise heating systems, switching them away from fossil fuel. Our analysis projects that in the period 2026-2030, the annual rate of renovations that switch fuel to low-carbon heating systems (HEATING ONLY and COMBINED) should reach 2.5% of the stock.
- Many studies only discuss ENVELOPE ONLY renovations without reference to renovating heating systems. Our analysis suggests, however, that policies on the intelligent replacement of heating systems should be given prominence, because the largest impact on CO_2 reduction is made by converting fossil fuel heating systems, mostly to efficient heat pumps[2]. Other important options are district heat, biomass (but only a few energy scenarios see its role increasing), hydrogen and e-fuels.
- Discussions about renovations should explicitly mention the nature of the renovations considered. Sometimes energy renovations only refer to envelope renovations, sometimes they also include replacements of heating equipment. Our analysis differentiates three groups of renovations: ENVELOPE ONLY renovations, HEATING ONLY renovations and COMBINED renovations that combine both. ENVELOPE ONLY renovations only improve the thermal integrity of buildings, and HEATING ONLY affect the heating system while COMBINED renovations improve the energy demand while also fully decarbonising the heating system. Full decarbonisation of the heating system is assumed for HEATING ONLY and COMBINED renovations.
- One of the main objectives of the Renovation Wave strategy is 'to at least double the annual energy renovation rate of residential and non-residential buildings by 2030 and to foster deep energy renovations.' The strategy is intended to mobilise 'forces at all levels towards these goals' that 'will result in 35 million building units renovated by 2030.' We confirm the importance of envelope renovations in at least 35 million dwellings by 2030. We also confirm the strategy's conclusion that 'fossil fuels will gradually disappear from heating and cooling.' In the scenario Fit for 55 REG, 41 million houses are projected to have a heat pump as heating equipment by 2030 (European Commission, 2021f). Our analysis provides similar data on renovations that involve changing the energy source (fuel). It shows that in the period 2022-2030, low-carbon heating should replace the heating system in more than 15 million dwellings (about half) which currently use oil or coal, and in around 25 million dwellings (one in four) currently using natural gas. In total, at least 40 million existing dwellings should switch their fossil fuel boilers to low carbon heating alternatives by 2030 (see **Table 1**). When installing hybrid technologies (with an electric heat pump as well as a fossil fuel boiler), the number of dwellings switching away from fossil fuel boilers needs to be around 25% higher.

[2] Complying with Renewable Directive Article 7, Calculation of the share of energy from renewable sources (HP methodology in Annex VII of RED).

— We note that problems can arise in the decarbonisation of dwellings which use oil or coal. Compared to dwellings heated by natural gas, a higher rate of heating system renovations is needed to guarantee a phase-out of oil and coal before 2040, as depicted in the energy scenarios. There is also a higher rate of envelope renovation because it makes poor economic sense to switch fuel first and insulate afterwards[3]. The main problem is that the replacement rate of 7% for dwellings with oil in the years before 2030 is very high (upper right panel in **Figure 2**). This rate is double the default rate of replacement historically[4], and calls for action beyond the phasing out of new oil or coal heating devices. For this particular problem, additional efforts are needed to investigate options for incentivising the replacement of fossil fuel-based heating devices even if they have not yet reached their end of life.

— For natural gas, the switch rate is 3.2%, allowing for only a marginal share of replacements to be new gas boilers. This will have a major impact on the gas boiler market. In our analysis, the annual replacement of gas boilers with new gas boilers is reduced from 3.7 million per year today to around 1.1 million by 2025 (see **Figure 3**). This can only occur if the low-carbon heating technology market grows fast enough to supply the remaining 2.6 million replacements.

— Our analysis reduces uncertainty about the speed with which the EU needs to change its fuel mix in buildings. If renovation actions are delayed and only start to take effect in 2026, the risk is that the total renovation rate (ENVELOPE ONLY, HEATING ONLY and COMBINED) would need to increase too quickly, to at least 5% for residential buildings currently fuelled by gas (compared to 1.3% of medium and deep renovations of the stock today, see **Figure 2**).

— Our results should encourage people to think hard about new heating equipment if we want to reach our climate targets. Even when considering state-of-the-art technology, the replacement of fossil fuel boilers by newer fossil fuel boilers should be discontinued as soon as possible for oil, and between 2025 and 2030 for natural gas, where possible. To tackle this problem, we propose an increase in efforts to harmonise technology options with the 2030 climate ambition. These findings could have policy consequences, for example, on Ecodesign and Labelling standards for new heating systems or for national measures, supporting the phase-out of fossil-fuel boilers.

— Our analysis gives a new perspective on ENVELOPE ONLY renovations, which only improve the thermal integrity of buildings. ENVELOPE ONLY renovations without a fuel switch remain important, and in our analysis are expected to take place in 1% to 1.6% of the total building stock annually. It is, however, important to differentiate dwellings by energy source. ENVELOPE ONLY renovation rates will increase for dwellings with non-fossil fuel heating from around 1.3% currently to between 2.0% and 3.3% from 2025 onwards. By contrast, energy renovations without a fuel switch to low-carbon heating would ideally stop happening around 2025 for dwellings currently using oil/coal, and soon after 2030 for dwellings using natural gas. ENVELOPE ONLY renovations decrease strongly for dwellings fuelled by oil and gas because of two mechanisms (see **Table 1**). First, ENVELOPE ONLY renovations for fossil-fuelled dwellings have to become marginal soon after 2030. These dwellings will eventually need a COMBINED or HEATING ONLY renovation because of the need to switch heating systems, with or without envelope renovation. Second, the required decarbonisation rate of heating systems is so high that any additional renovation for dwellings currently using fossil fuel must also entail a switch to low-carbon heating systems. Envelope renovations more than double for fossil-fuelled dwellings, however ENVELOPE ONLY renovations do not reduce enough fossil fuel despite reaching an average energy reduction of 65% at the dwelling level. Therefore, envelope renovations in dwellings currently using fossil fuel will need to reorient towards COMBINED renovations that combine efficiency improvements in the building shell with a fuel switch.

— This scientific evidence points to the importance of phasing out new fossil fuel boilers in the relative short term. Policy initiatives could make reference to the fact that the renovation mix is not in conflict with the 'energy efficiency first' principle. This principle was defined in the Regulation on Governance of the Energy Union and Climate Action as *'taking utmost account of alternative cost-efficient energy efficiency measures to make energy demand and energy supply more efficient.'* Also, *'energy efficiency improvements need to be made whenever they are more cost-effective than equivalent supply-side solutions.'* In fact, models behind energy scenarios often conclude that renovations involving fuel switches – even some HEATING ONLY renovations – are cost-effective at the macro level of the energy system. Today, the cost-effectiveness is, however, not always reflected at the level of each household, due to a

[3] Hybrid systems (heat pump/boiler) or heat pump add-ons to an existing boiler were not analysed separately.
[4] This rate includes like-with-like replacements (eg old oil boiler replaced with new oil boiler).

number of reasons ranging from limited internalisation of carbon costs, to subsidies for fossil fuel, distorted electricity prices and lack of financial motivation in a rental property. This study does not provide quantitative results at household level.

- There is a need to quantify efforts to decarbonise buildings. Investment in the residential sector will reach EUR 194 billion annually in 2021-2030 in the scenario Fit for 55 REG (European Commission, 2021h). This is more than double the historic investment in the period 2011-2020. Our study confirms the rapid changes and concludes that, before 2030, the market for envelope renovations could double and the market for heating system renovations triple.
- The rapid increase in energy and heating system renovations may result in bottlenecks regarding material use, sector growth or the supply of specific technologies such as heat pumps. Our analysis does not take into account restrictions or constraints on this. Our approach uses fossil fuel reduction from energy scenarios that may, however, include such constraints.

Table 1 Renovations in residential buildings (million dwellings)

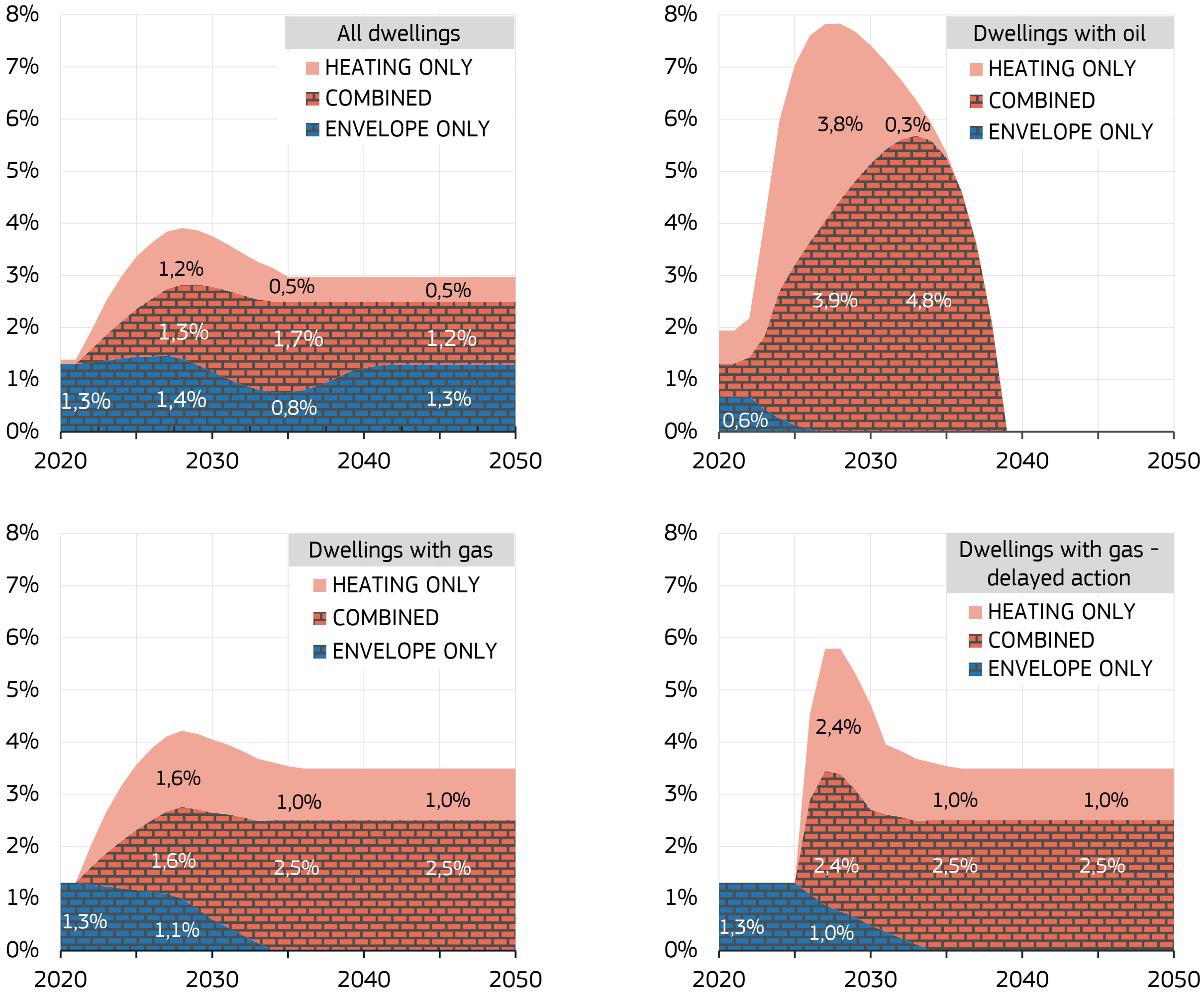
		2010-2020	2021-2030	2031-2040	2041-2050
Envelope renovations	ENVELOPE ONLY non-fossil	12	19	19	29
	ENVELOPE ONLY fossil	16	15	0	0
	COMBINED	2	22	38	26
	Total	30	56	57	56
Heating system renovations	HEATING ONLY	2	21	11	11
	COMBINED	2	22	38	26
	Total	4	43	49	37
Total renovations		32	77	68	68

Note: There were 227 million dwellings in 120 million buildings in 2019; Future years based on the renovation scenario FOCUS that has increased renovation efforts in the most carbon intensive dwellings (more details in chapter 7.1); Totals may differ due to rounding; Historical data based on proportional distribution. *Source:* JRC

Main findings

One of our main findings is that many more households should participate in energy or heating system renovations: around 30% of EU households by 2030 and more than 85% by 2050. We define three types of renovation (**Figure 1**): an ENVELOPE ONLY renovation of the building without changing energy source for heating, a HEATING ONLY renovation and a COMBINED renovation that combines both. By 2050, we estimate that 42% of the current dwelling stock will have had a COMBINED renovation and 15% a renovation that involves replacing only the heating system. As a result, dwellings currently using fossil fuels almost entirely switch away from fossil fuel. By 2050, we also estimate that 75% of the current dwelling stock (using both fossil and non-fossil fuel) will have undergone an envelope renovation. In dwellings currently using fossil fuel (around 60% of total stock), this is almost entirely a COMBINED renovation. In dwellings currently not using fossil fuel (around 40% of total stock), this is by definition an ENVELOPE ONLY renovation to improve the level of energy efficiency.

Figure 2 Annual renovation rate in dwellings as share of 2019 stock, by type of renovation.



Note: Based on the renovation scenarios FOCUS and DELAYED. In FOCUS, there are increased renovation efforts in the most carbon intensive dwellings. In DELAYED, renovations scale up only in 2026, rather than in 2022 (more details in chapter 7.1)

Source: JRC.

The four boxes below summarise the main findings of our analysis, based on changes in the energy use of buildings derived from 12 energy scenarios by different organisations (discussed in Chapter 2 and detailed in Annex 1 and Annex 2), providing context (top left), relevant data on renovations (top right), and specific conclusions for oil (bottom left) and natural gas heating (bottom right).

Fossil fuel use in buildings

- **Today, two thirds of the energy used for space heating** comes from **fossil fuels**;
- Natural gas, oil* and coal provide **38%, 15% and 4%** respectively, of the final energy for EU **space heating** in residential buildings. The remaining energy is supplied by biofuels (24%), district heat (10%), ambient and electricity (5% each);
- **By 2030**, the average reduction of **carbon emissions from buildings is 40%**, across all energy scenarios covered, when compared to 2019; this equals the reduction that took place in the last 30 years;
- In the Fit for 55 MIX scenario, carbon emissions are **cut in half by 2030**;
- **By 2040, the reduction is 75% by 2040** compared to 2019;
- **80% of total coal** in buildings is used **in Poland and Czechia**.

(*) including LPG (Liquid Petroleum Gas)

Renovation of existing residential dwellings

- Between 2022 and 2030, a 2.5% energy renovation rate results in a **15% reduction of total energy use** of existing buildings, based on an average 67% reduction of energy demand in 22% of the dwellings;
- The required oil reduction for 2030 is **4 times the above figures and the gas reduction must double,** so decarbonisation of heating systems and fuel switching are vital;
- By 2030, **60%** of coal and oil boilers disappear and also **1 in 4** natural gas boilers. This will require **deep renovations** and a **doubling** of the number of dwellings on **heat pumps and district heating by 2030** if biomass remains more or less unchanged;
- Before 2030 the market for **energy renovations doubles** and the market for **heating system renovations triples**;
- By 2050, there is a **48% reduction of total energy use** if 71% of existing dwellings are renovated.

Oil heating *

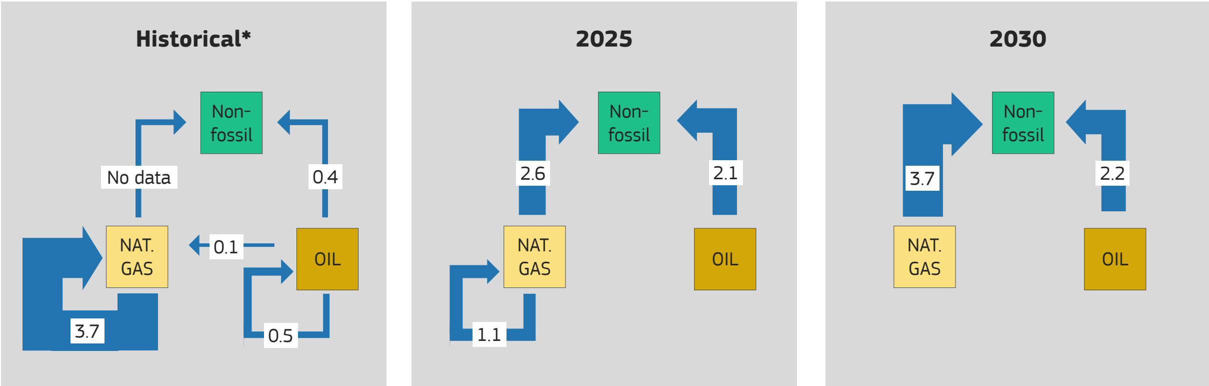
- **78% of oil** is used in Germany, France, Belgium and Spain; the **per capita top 5** is: Luxembourg, Ireland, Belgium, Germany and Austria;
- The majority of oil-supplied buildings are located in **rural areas**; **oil is 20% and LPG 5%** of the total fossil fuel use in buildings;
- An old oil boiler is often replaced by a newer generation oil boiler; in Germany **80% of replacements are currently with oil again**, 15% switch to natural gas and around 5% switch to low-carbon heating systems;
- **60% average reduction of oil** use by 2030 requires that the replacement rate of **residential oil boilers needs to increase to 7%** by 2025; the current rate in Germany is 3.4%.
- Oil boilers can only be **replaced by low-carbon heating systems** to meet our targets; no new oil heating boilers should be the norm as soon as possible.

(*) In the report, we use "oil" for oil products that include LPG

Natural gas heating

- Natural gas use is **still increasing** in some countries;
- **70% of natural gas** is used in Germany, Italy, France and the Netherlands; the **per capita top-5** is: Luxembourg, the Netherlands, Belgium, Italy and Hungary.
- **30% average reduction of gas use** by 2030 requires the removal of the gas boiler in **25% of dwellings** that currently use gas;
- An old gas boiler is typically replaced by a newer generation boiler consuming less fuel. **However by 2025, only 30% of replacements can stay with gas,** reducing the **market size of new gas boilers** from 3.7 billion today to around 1.1 billion;
- **As of 2026, the number of new gas boilers need to become marginal.**
- The replacement rate of gas boilers with low-carbon systems can remain below the default replacement rate **(3.5%)** but if actions are delayed, the net replacement rate has to scale up very suddenly from 2025 to **4.8%** to make up for the lost time.

Figure 3 Annual replacement of space heating systems in existing residential buildings (million dwellings per year)



Note: (*) Historical switching of oil to non-fossil is an EU average while the switch from oil to gas is based on data for Germany.
Note: Based on scenario FOCUS that assumes increased renovation efforts in the most carbon intensive dwellings; Source: JRC

Related JRC work

— The energy scenarios tool (European Commission, 2021b) encourages the exploration of the latest EU Reference Scenario and Fit for 55 results for all EU countries, including data on the buildings sector.

— The report (Zangheri, et al., 2021) describes the progress of Member States in implementing the Energy Performance of Buildings Directive.

— The report (Toleikyte & Carlsson, 2021) provides projections on RES heating and cooling per Member State

— The report (Jiménez-Navarro, Filippidou, Kavvadias, & Carlsson, 2021) discusses reporting guidelines in the context of the Energy Efficiency and Renewable Energy Directives for district Heating and Cooling.

— The report (Della Valle & Bertoldi, 2021) discusses how citizens could contribute to the low-carbon energy transition by investing in energy efficiency

— The report (Economidou, Della Valle, Melica, Valentini, & Bertoldi, 2021) reviews current best practices of financing energy renovations at regional level

— The report (Zangheri, et al., 2020) is about building energy renovation for decarbonisation and Covid-19 recovery at European and national level.

— The report (Tsiropoulos, Nijs, Tarvydas, & Ruiz, 2020) presents a comparison of energy scenarios aiming at climate neutrality by 2050, focusing on the uptake of clean and low-carbon energy technologies.

— The report (Filippidou & Jimenez Navarro, 2019) discusses the cost-effective energy transformation of Europe's buildings.

— The report (Kavvadias, Jiménez-Navarro, & Thomassen, 2019) discusses the decarbonisation of the EU heating sector in the context of the integration of the power and heating sectors.

— The report (Carlsson, et al., 2019) provides information on technology synergies and provides JRC modelling results on electricity use for building heating and cooling needs in a zero-carbon scenario.

— The report (Nijs, Ruiz Castello, Tarvydas, Tsiropoulos, & Zucker, 2018) focuses on the uptake of clean and low-carbon energy technologies and provides JRC modelling results on sectoral final energy use.

— The report (Pavel & Blagoeva, 2018) discusses the competitive landscape of the EU insulation materials industry for energy-efficient buildings.

Quick guide

The report explains the role of fossil fuel use in buildings today (Chapter 2), the building stock and how it is heated (Chapter 3) and the choice of scenarios included in the comparison analysis (Chapter 4). The next two chapters address the projected reduction of fossil fuel use (Chapter 5) and the projected use of non-fossil fuel energy (Chapter 6). The deployment of insulation and low-carbon technologies are discussed in terms of technology scale-up (Chapter 7) and investments (Chapter 8). Chapter 9 discusses the policy challenges of promoting both energy and heating system renovations. The conclusions can be found in Chapter 10.

Disclaimer: The conclusions and recommendations of this report do not imply any policy position of the European Commission.

1 Introduction

In July 2021, the European Commission adopted a package of proposals (European Commission, 2021a) to make the EU's climate, energy, land use, transport and taxation policies fit for reducing net greenhouse gas (GHG) emissions by at least 55% by 2030, compared to 1990 levels. Achieving these emission reductions in the next decade is crucial to Europe becoming the world's first climate-neutral continent by 2050 and making the European Green Deal a reality.

The package stresses that homes and public buildings must be renovated to use more renewable energy, and to be more energy efficient. The Commission proposes to renovate at least 3% of the total floor area of all public buildings annually. It also proposes to set a benchmark of 49% of renewables in buildings by 2030 and to increase the use of renewable energy in heating and cooling by +1.1 percentage points each year, until 2030.

In the Fit for 55 scenarios from the energy modelling that supported this package, carbon emissions from buildings are cut in half by 2030. This is challenging, given that in the last decade, carbon emissions have reduced by around 20% only (using the same 2019 basis). It also mentions that the bulk of the investment is expected in the residential sector.

This was already acknowledged in the Communication of the Climate Target Plan in 2020, which pointed to *'the challenge of mobilising significant additional investments in the coming decade'*. The Impact Assessment accompanying the Communication of this Climate Target Plan[5] explores options for 50-55% greenhouse gas emissions reduction in pursuit of climate neutrality by 2050. It demonstrates that an emissions reduction of 55% by 2030, compared to 1990 levels, is both economically feasible and beneficial for Europe, with proper policies in place.

Hotmaps (Hotmaps, 2021) conclusions indicate that while emissions decline significantly, reductions of more than 80% by 2050 constitute a major challenge. Even if it is assumed that district heating and electricity supply is almost fully decarbonised by 2050, emission reductions amount to around 83% in the ambitious policy scenario.

(Tsiropoulos, Nijs, Tarvydas, & Ruiz, 2020) provides evidence that in the next ten years, we need to accelerate the development of clean technologies if we are to reduce coal use in the EU by over 60% and natural gas and oil use by over 25%. The study concludes that by 2030 in housing, we need to foster deep energy renovations and replace at least a quarter of fossil heating systems, mainly with heat pumps and district heating. (Boza-Kiss, Bertoldi, Della Valle, & Economidou, 2021) highlights the importance of the renovation of existing building stock: 90% should be renovated deeply or demolished by 2050, in order to achieve a climate-neutral building stock.

At the global level, (International Energy Agency, 2021) claims that for net zero emissions by 2050, electricity plays a key role in buildings. The report also says that bans on new fossil fuel boilers need to start being introduced globally in 2025, driving up sales of electric heat pumps.

The current annual renovation rate of the existing building stock varies from 0.2-12%[6] (European Commission, 2019). This number varies depending on the quality of renovation. While 0.2-0.3% of existing building stock undergoes deep renovations (achieving approximately 60% savings), 12% of the building stock undergoes some level of renovation (with half of these buildings achieving less than 3% savings).

This study is undertaken to shed light on the challenges related to reducing the consumption of fossil fuels in buildings. We quantify the role of renovations of heating systems that involve switching away from fossil fuel to low-carbon alternatives.

[5] COM(2020) 562

[6] This number shows the yearly renovated floor area

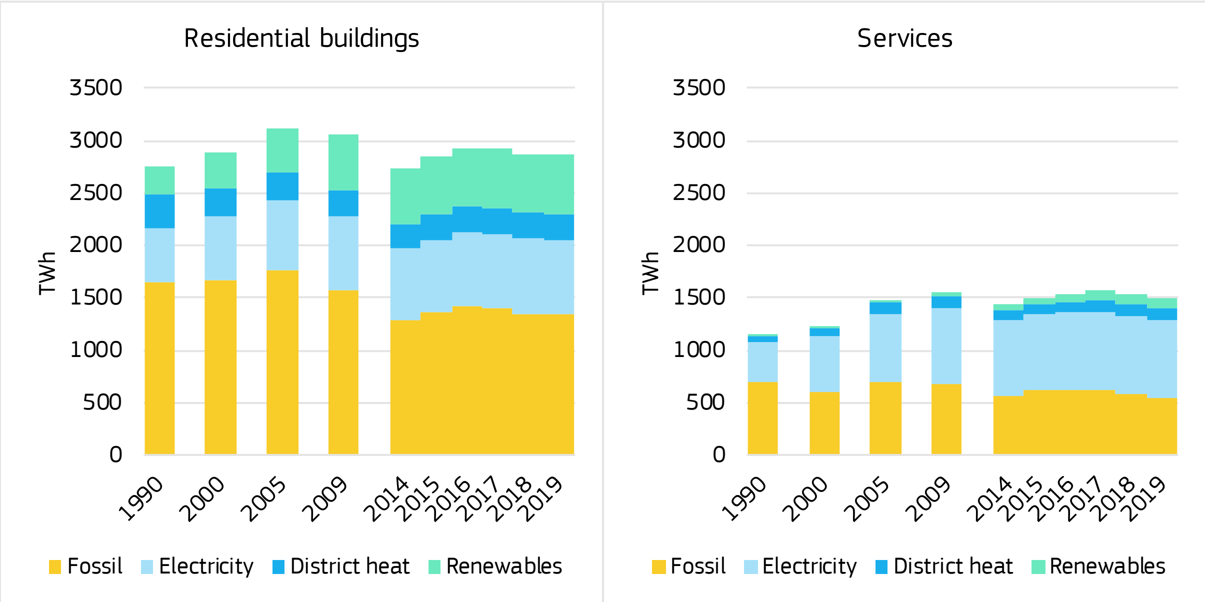
2 Historical fossil fuel use in buildings

From the beginning of the century (2000-2019), energy consumption in EU buildings increased by over 6%, while the building stock[7] increased by more than 15% (indicating gradual improvements in energy efficiency). This increase of energy use was entirely caused by the growth of the services sector (Figure 4). Energy use in the services sector increased by 23%, mostly in the period 2000-2010, while energy use in the residential sector decreased marginally (around 1%). The services sector now accounts for one third of energy use in buildings, and the residential sector two-thirds (65%). In the last five years (2015-2019), total energy consumption in the buildings sector has fluctuated around 4400 TWh without major changes, mostly determined by fluctuations of the weather conditions.

2.1 Historical total energy use

In the period 2000-2019, the use of fossil fuel in buildings dropped by over 16% and the use of renewable energy increased by 87%. The period 2015-2019 was more settled, with a slight decrease in the use of fossil fuels (-4.5%), compensated by an increased use of renewables (+12.3%) and by electrification (+4.6%), leaving total energy use almost unchanged.

Figure 4 Final energy consumption in residential and services sectors (*)



Source: JRC; *Note:* 2009 is used instead of 2010 because 2010 was exceptionally cold (almost 3500 heating degree days) and climate corrected figures are not available in Eurostat. *Source:* JRC, based on (Eurostat, 2021)
(*) Services does not include agriculture

In the residential sector in 2000-2019, fossil fuel use dropped by 20%, district heating contracted by 8%, electrification increased by 16% and utilisation of renewables jumped by 65%. In the last five years, changes were more subtle: a decrease in fossil fuel use by 2%, and an increase in electrification by 2%, district heating by 1% and renewables by 5%.

In Figure 5, more details are provided on the changes by fuel and by heat source. The largest change observed is the utilisation of ambient heat. Ambient heat is energy from the air, ground or water that is locally available. Electric heat pumps use this ambient heat and electricity for heating and cooling. Heat pumps were hardly used in the beginning of the century but the use of ambient heat has increased 70% in the last five years.

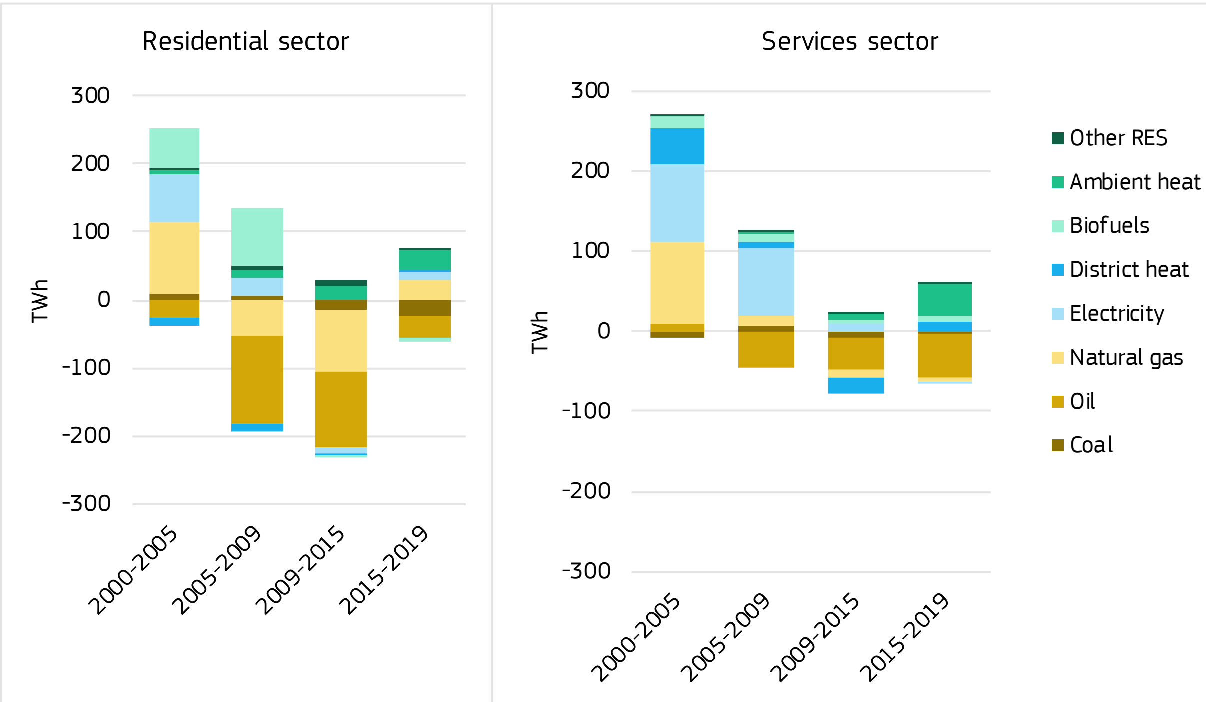
[7] Based on data up to 2016

Solar energy increased fourfold between 2000 and 2019, but its increase slowed to 14% in the last five years. Use of oil products dropped by half in 2000-2019, and use of coal stayed almost constant with the exception of a 20% drop in 2019. Gas usage remained constant. Solid biofuels experienced high growth at the beginning of the century, but decreased slightly in the last five years.

In the service sector in 2000-2019, fossil fuel use dropped by only 7%, district heating increased by 75%, electrification increased by 34%, and renewables increased sixfold. In the last five years, changes were more subtle: fossil use decreased by 10%, district heating increased by 13% and renewables by 81%. The biggest changes were observed in the utilisation of ambient heat – a 173-fold increase from the beginning of century and 300% over the last five years and solar – an almost fourfold increase in 2000-2019 and 15% in last 5 years. The use of oil and coal products dropped by half in 2000-2019. Gas usage increased by 30% (2000-2019). Solid biofuels tripled.

A comparison is provided in Figure 5 between milestone years (in five-year steps). It is worth nothing the difference in meteorological conditions between the selected years. For example, 2010 was the coldest year since the century began (almost 3500 heating degree days (HDD) in comparison to 2800 HDD in 2020 in the EU), affecting overall energy consumption in both residential and commercial buildings, and therefore affecting the use of all fuels. Cooling degree days also fluctuate significantly between milestone years, but due to lower cooling demand (there was a variation of only 60-130 cooling degree days from the beginning of the century), its effect on energy demand in buildings is considerably lower. Moreover, cooling demand only affects electricity use.

Figure 5 5-year period* changes in residential and services sectors



Note: Oil includes liquid oil products and LPG.
(*) 2009 was used as a milestone year due to extreme cold in 2010 and climate corrected figures are not available in Eurostat.
Source: JRC, based on (Eurostat, 2021)

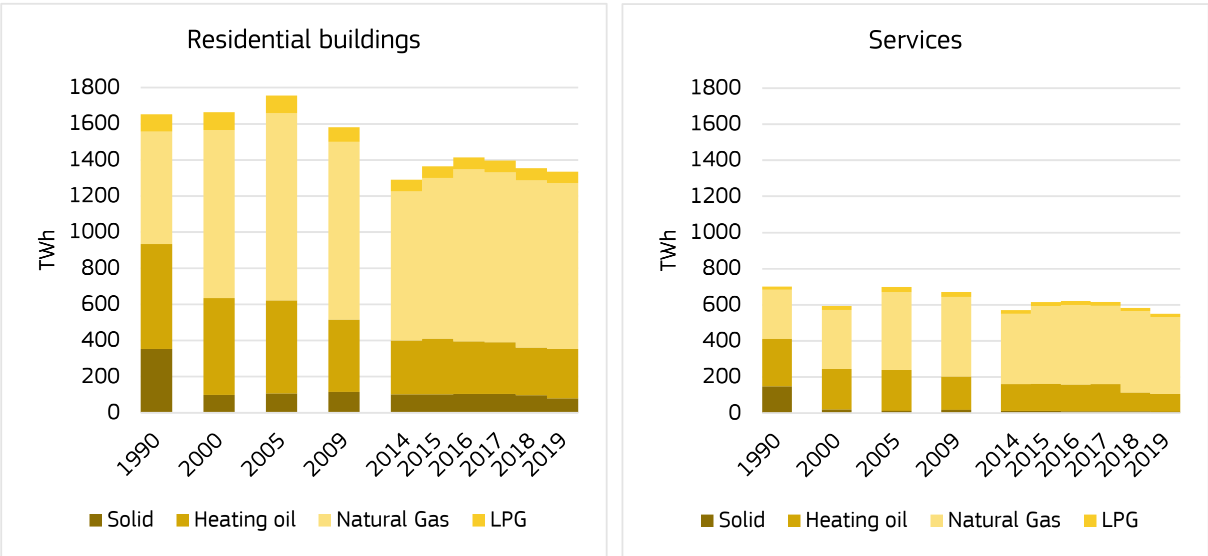
In 2010, the dominant fuels in the residential buildings sector were gas (33%) followed by electricity (23%), solid biofuels (16%) and oil (15%), while in services, 46% of fuel used was electricity, 29% was gas and 13% was oil. In 2019 the situation was similar. In residential buildings, gas still covers 32% of final demand, electricity 25%, solid biofuels 17% and oil 12%. The service sector is still dominated by electricity (49%), followed by gas (28%) and oil (8%). The biggest changes are observed in the structure of renewables. If in

2010, ambient heat covered less than half a percent of demand in the services sector, in 2019 it reached 3.5% (or half of the renewables directly used in the service sector). In residential buildings, ambient heat also jumped from 0.7% in 2010 up to 2.5% in 2019, but solid biomass remains the dominant renewable fuel there.

2.2 Fossil fuel use

Overall reliance on fossil fuels in the buildings sector decreased over the last decade, mainly by reducing the consumption of coal and oil products (a drop of around 35% in the period 2009-2019), led by the services sector, where by 2019, coal usage was almost complete gone (only 8 TWh left) and consumption of oil products were down by 47%. The reduction of oil use in the residential sector was the highest between 2005 and 2009 (21%). In the period 2014-2019, the reduction slowed down to 8%. Natural gas reduction remained very limited in this period (a drop of only 6%). The last five years show a slightly different trend in gas consumption. Switching away from coal (reduced by 32% in residential and 31% in services) and oil products (reduced by 12% in residential and 20% in services) in the buildings sector, resulted in an increase in natural gas consumption of almost 2% (driven by the residential sector with a 3.2% increase).

Figure 6 Final energy consumption of fossil fuels in the residential and service sector



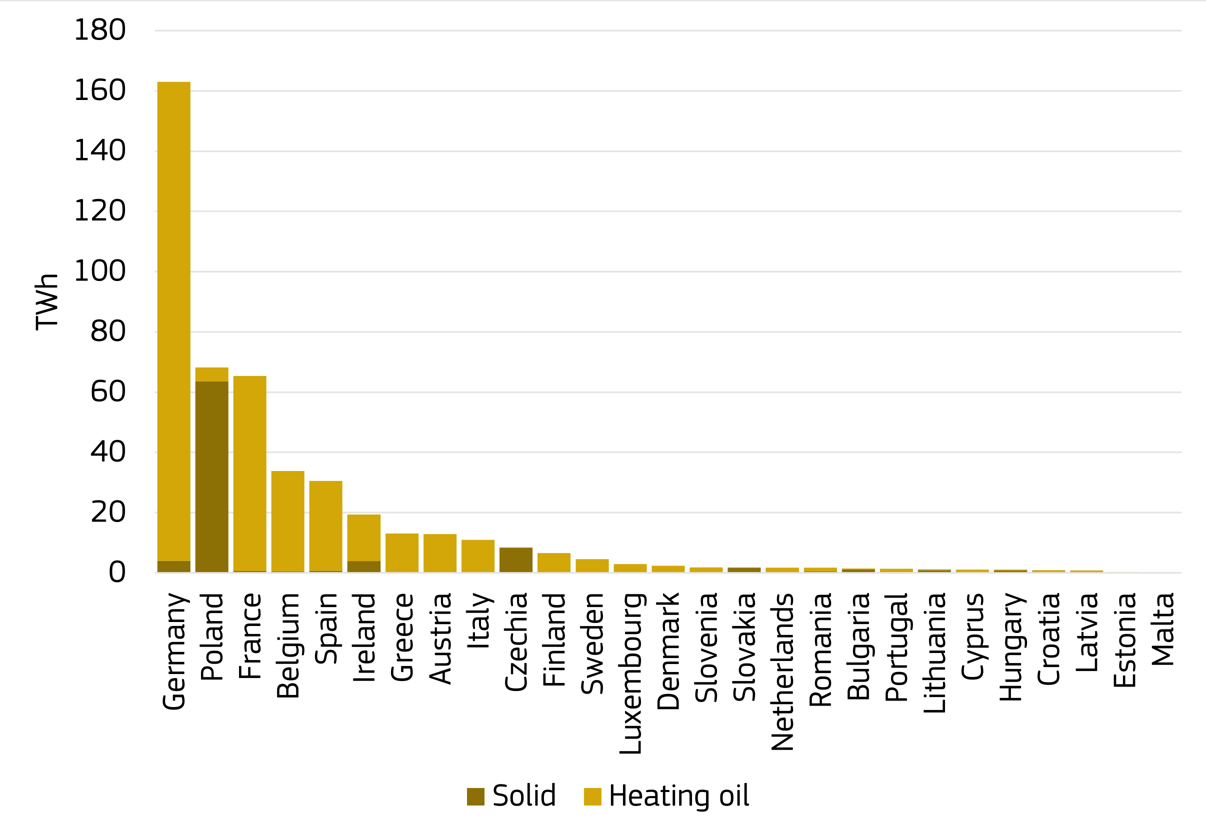
Source: JRC based on (Eurostat, 2021)

The 3 most populated counties in the EU (Germany, Italy and France) are responsible of 60% of the fossil fuels directly used in the buildings sector. Germany relies heavily on natural gas and oil products and Italy and France rely mainly on natural gas. These three countries are also top three biggest consumers of natural gas in the EU buildings sector.

The three largest consumers for oil products are Germany (consuming around 160 TWh of heating oil - **Figure 7**), France (65 TWh) and Belgium (33 TWh). The number of people living in these countries is one of the main reasons for this. Eliminating the population effect, the highest consumption of oil products in the buildings sector is in Luxemburg with 4800 kWh per capita, followed by Ireland (3200 kWh per capita) and Belgium (almost 3000 kWh per capita), leaving Germany in fourth place with 1900 kWh per capita (**Table 2**).

The single largest consumer of coal in the buildings sector is Poland (64 TWh), followed by Czechia (8 TWh) and Ireland (4 TWh). On a per capita basis, Poland remains the biggest consumer of coal (1700 kWh per capita), followed by Ireland and Czechia (around 800 kWh per capita each).

Figure 7 Final energy consumption of coal and heating oil in residential and service sector by country, 2019



Source: JRC based on (Eurostat, 2021)

Table 2 Top ten countries with highest per capita fossil fuel use in buildings

	Solid (coal or peat)	Heating oil	Gas
1	**Poland**	*Luxembourg*	*Luxembourg*
2	*Ireland*	Ireland	**Netherlands**
3	Czechia	**Belgium**	**Belgium**
4	*Lithuania*	**Germany**	**Italy**
5	*Slovakia*	Austria	**Hungary**
6	*Bulgaria*	*Cyprus*	**Germany**
7	*Hungary*	Greece	**Czechia**
8	*Germany*	**France**	**France**
9	*Belgium*	*Slovenia*	**Romania**
10	*Latvia*	**Spain**	**Poland**

Note: Countries in **bold** have a consumption higher than 30 TWh.
Countries in *italic grey* have a consumption lower than 5 TWh. *Source*: JRC based on (Eurostat, 2021)

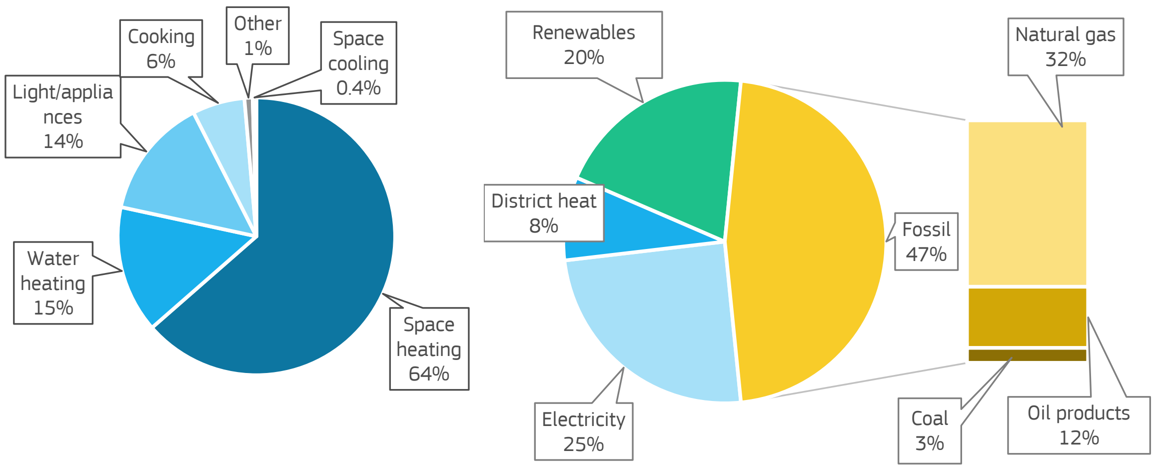
2.3 Residential buildings energy uses

Information on energy end use in the buildings sector at EU level is limited. Eurostat provides data only for residential buildings, and a full EU balance is only available for 2019. As several Member States provide wider temporal coverage, individual countries will be used as examples to better illustrate current trends.

It is evident (Figure 8) that the majority of energy use in residential buildings is for space (64%) and water (15%) heating. The share of heating is high across the majority of EU countries (Germany 66%, France 65%, and Finland 67%). The share is lower in southern countries only (Spain 43%, Portugal 28%), but even there, space cooling accounts for less than 1% of total energy consumption in residential buildings.

Space cooling consumes below 0.5% of final energy in residential buildings. In service buildings, the share of space cooling (and general air conditioning) is higher, but it is not the prime objective of this report – the majority of cooling is fuelled by electricity and renewables, so any increase in space cooling does not tend to increase the direct fossil fuel use in buildings.

Figure 8 End use in EU by end use (left) and fuel (right) in residential buildings (2019)



Note: Oil products consist of liquid oil products (10%) and LPG (2%). Source: JRC based on (Eurostat, 2021)

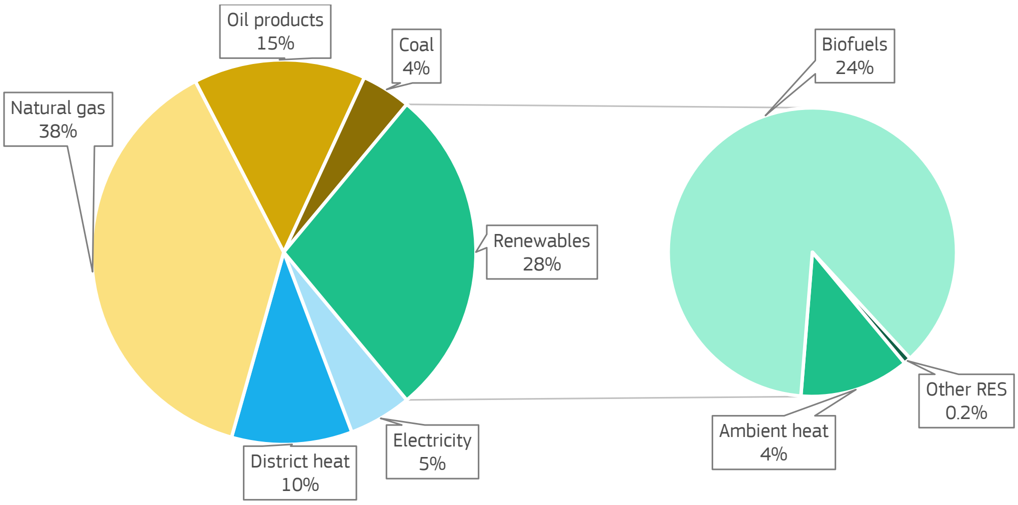
All fossil fuels in the residential sector are used for heat-related activities: over 77% for space heating, 17% for water heating and 6% for cooking. It is very unlikely that consumers would continue to use fossil fuels (especially oil and coal) for hot water and food preparation if they were eliminated from space heating.

2.3.1 Space heating

In 2019, around two thirds of the energy used for space heating came from fossil fuels. 57% of EU energy used for residential space heating was based on individual fossil fuel boilers or stoves (38% natural gas, 14% oil products, 5% coal). Only 27% came directly from renewables (dominated by solid biomass at 23%). Electricity and district heat accounted for 5% and 11% respectively. Around 40% of electricity and 70% of district heat came from fossil fuels. The biggest change in the space heating sector came from the rapidly increasing utilisation of ambient heat (72% increase in the last five years), but in absolute terms, the share of ambient heat in space heating remained negligible (4%).

District heat (an important contributor to space heating) relies heavily on fossil fuel. In 2014, 76% of district heat was fossil-based. In the last five years the changes were minimal – the share of fossil fuels decreased by only 4% and is dominated by natural gas at 36%, and coal at 32%.

Figure 9 Final energy for space heating by energy source (2019)

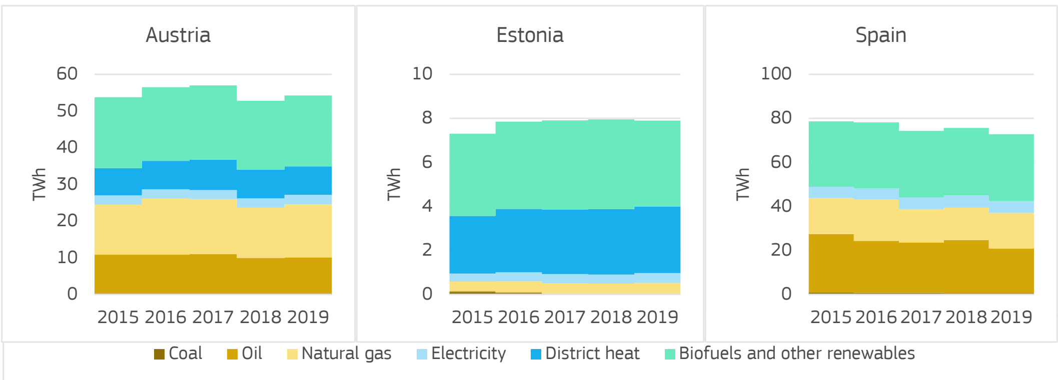


Note: Oil products consists of 13% of heating oil and 2% Liquid Petroleum Gas; Source: JRC based on (Eurostat, 2021)

It is important to understand the considerable differences between the Member States when it comes to energy consumption for space heating. For example, Estonia relies heavily on district heating and renewables, while in Spain and Austria, natural gas and oil play an important role. There have been no dramatic changes at national level over the last decade. Based on the data, we can conclude that oil utilisation for space heating is shrinking, but all other differences are likely to have been caused by meteorological conditions.

Stand-alone heating systems provide around 90% of EU residential heat supply and district heating supplies the remaining 10%.

Figure 10 Fuels used for space heating in selected countries.



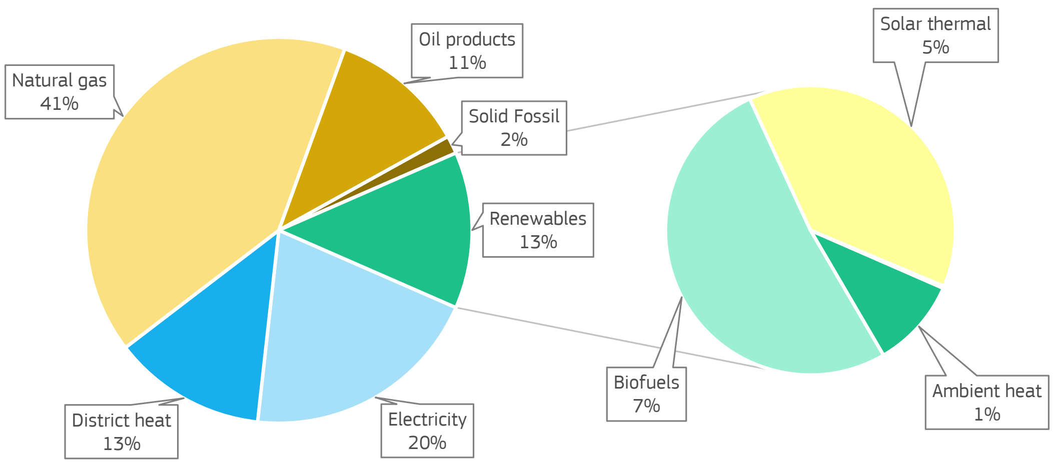
Note: Oil products consists of liquid oil products and LPG. Source: JRC based on (Eurostat, 2021)

2.3.2 Hot water

54% of the energy used for hot water is fossil fuel-based, with only 12% from renewables. The dominant fuel in hot water preparation is natural gas (41%), followed by electricity (21%) and district heat (13%).

In the majority of residential buildings, hot water preparation is linked to the space heating. For example, if natural gas is used for the space heating, in most cases it can also be used for hot water preparation. The exception is solid fuels (both coal and biomass), where hot water preparation is usually replaced or supplemented by electrical and/or solar hot water heaters. Independently of the fuel used for space heating, since 2000, there appears to be a trend of adding solar thermal for hot water preparation. Nevertheless, solar thermal currently accounts for only 5% of hot water preparation, mainly in southern Europe where there is high resource availability and western Europe with strong policy support.

Figure 11 Fuel composition in hot water preparation EU (2019)



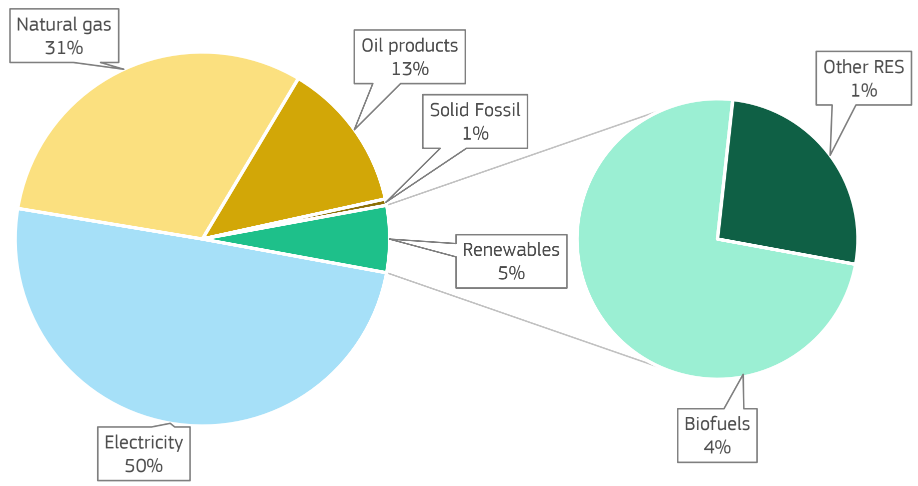
Note: Oil products consists of 8% of heating oil and 3% Liquid Petroleum Gas; Source: JRC

2.3.3 Cooking

Although cooking in residential buildings is, at 49%, dominated by electricity, 45% of the energy used is fossil fuel-based: natural gas alone accounts for 31%. Only 6% of the energy used for cooking is from renewable sources.

The higher rate of electrification for cooking is based on a higher level of convenience: if natural gas is available for space heating, in most cases it is also used for cooking. In most other cases, electricity is the preferred option.

Figure 12 Fuel composition for cooking EU (2018)



Note: Oil products is only Liquid Petroleum Gas; Source: JRC based on (Eurostat, 2021)

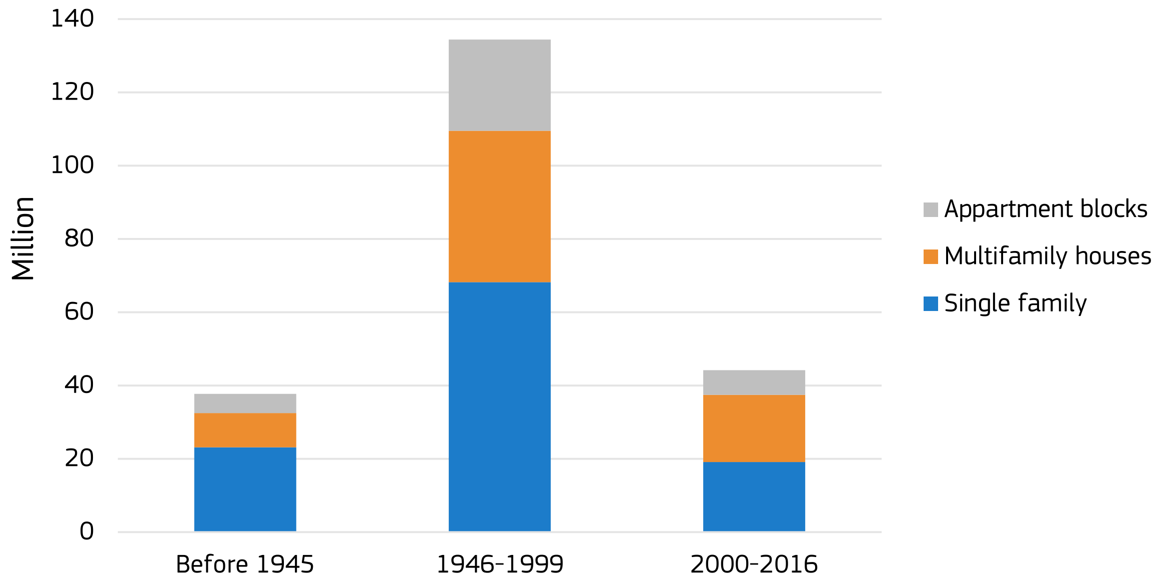
3 Building and heating system stock

3.1 Residential dwelling stock

To estimate renovation needs, the number of existing buildings and heating systems needs to be known. For the residential sector, this report uses dwellings[8] as the basis for analysis. The number of dwellings is higher than the number of buildings because multifamily houses, flats and terraced houses (houses joined together by their side walls) have more than one dwelling. Using the latest available data from (OECD, 2021), there were 227 million dwellings in 120 million buildings in 2019. In that year, 46.1% of the EU *population* lived in flats, more than one third (34.8%) lived in detached houses and almost one fifth (18.5%) lived in semi-detached or terraced houses (Eurostat, 2021).

Rather than population, it is more useful to look at dwelling stock. The majority of dwellings[9] (62%, **Figure 13**) were built between 1946 and 1999, and will need building envelope renovation to be brought in line with current energy efficiency regulations. This segment also has the highest potential to undergo deep renovation, resulting in high energy savings. Another 21% of dwellings were built after 2000 and tend to have better heat insulation, therefore offering less energy-saving potential. The smallest dwelling group (17%) was built before 1946. Despite being the oldest dwelling group, it may have the lowest renovation potential: partly, because of having historic significance and belonging to heritage sites, and partly because of low value (for example, located in unattractive locations or being in bad shape).

Figure 13 Residential dwelling stock by construction period



Source: JRC based on (Hotmaps, 2021)

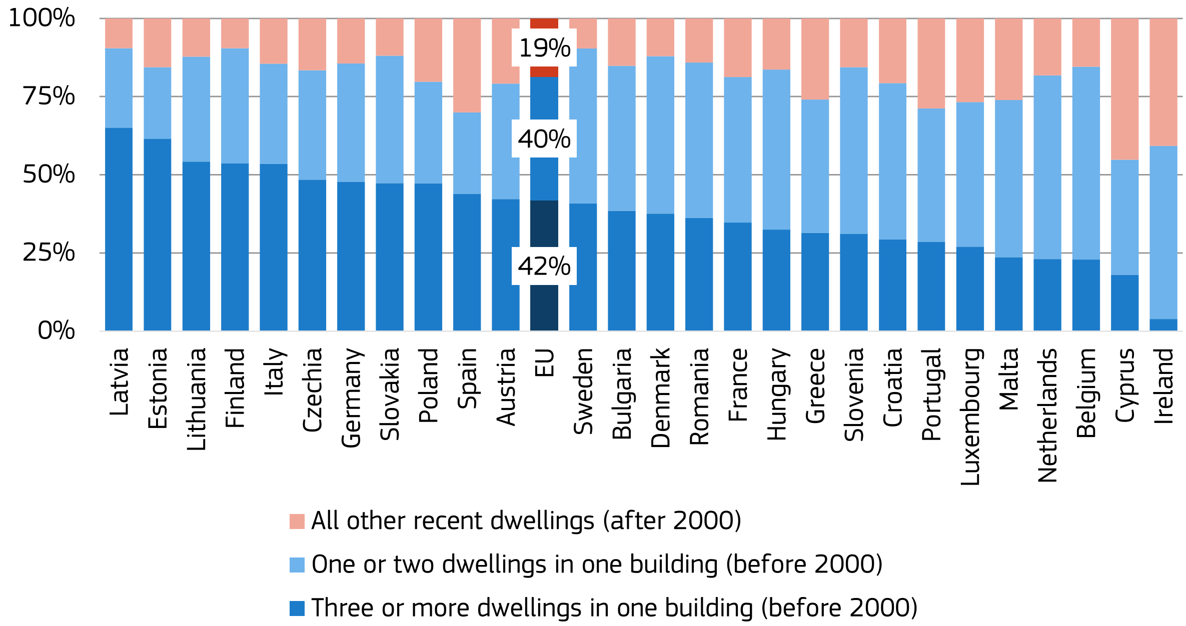
Based on data from (European Commission, 2021g) and (OECD, 2021), 19% of dwellings were built after the year 2000 and 81% before 2000. At EU level, 42% of dwellings date from before 2000 and are part of a building with more than three dwellings (**Figure 14**). This is higher than the number of dwellings in a building with one or two dwellings (40%), and is important because medium or deep energy renovations cannot easily be done at the level of a single dwelling. Similarly, renovations involving a fuel switch require a change to the

[8] Census statistics define a dwelling as 'a statistical abstraction denoting housing accommodation appropriate for occupation by one household'. https://ec.europa.eu/eurostat/cache/metadata/en/cens_01ndws_esms.htm

[9] Based on occupied dwellings from (Hotmaps, 2021). Occupied dwellings seem to be in line with the total number of dwellings from (European Commission, 2021g) suggesting an overestimation of unoccupied dwellings.

heating system of the total building. Country differences are large, with pre-2000 buildings containing at least three dwellings ranging from below 25% (Malta, the Netherlands, Belgium, Cyprus and Ireland) to higher than 50% (Latvia, Estonia, Lithuania, Finland and Italy).

Figure 14 Residential dwelling stock by construction period and number of dwellings in a building

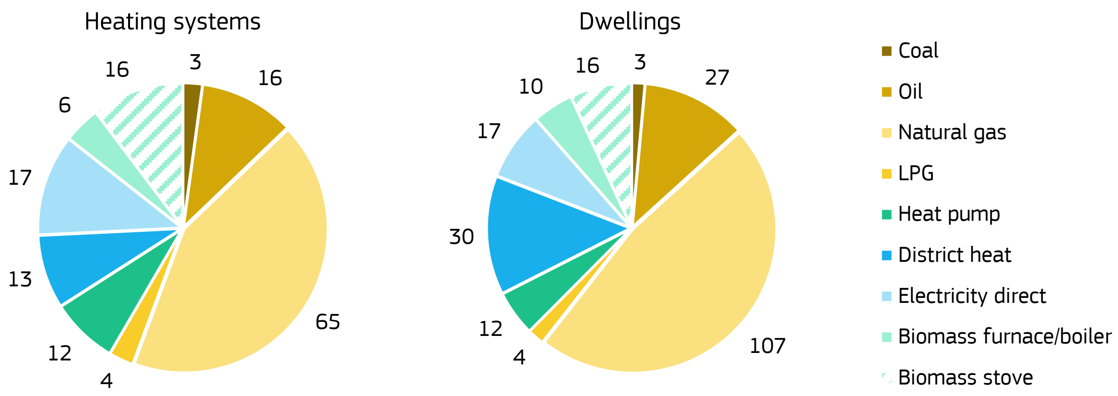


Source: JRC based on (European Commission, 2021g)

3.2 Residential heating system stock

The number of dwellings by heating fuel is estimated based on the number of heating systems. Following sources have been combined to estimate the number of heating systems: (European Commission, 2016a), (Bioenergy Europe), (Destatis, 2021) and (Eurogas, 2015). Reliance of residential space heating on fossil fuels can be expressed in different ways. Around 60% of the heating systems and dwellings are fossil based (88 out of 152 million heating systems and 142 out of 227 million dwellings). When including heat pumps and other electric heating, we can also conclude that in 2019, 75% of the dwellings are dependent on fossil fuel (62% directly fossil + 13% indirectly).

Figure 15 Number of heating systems and dwellings by primary heating fuel in 2019 (millions),

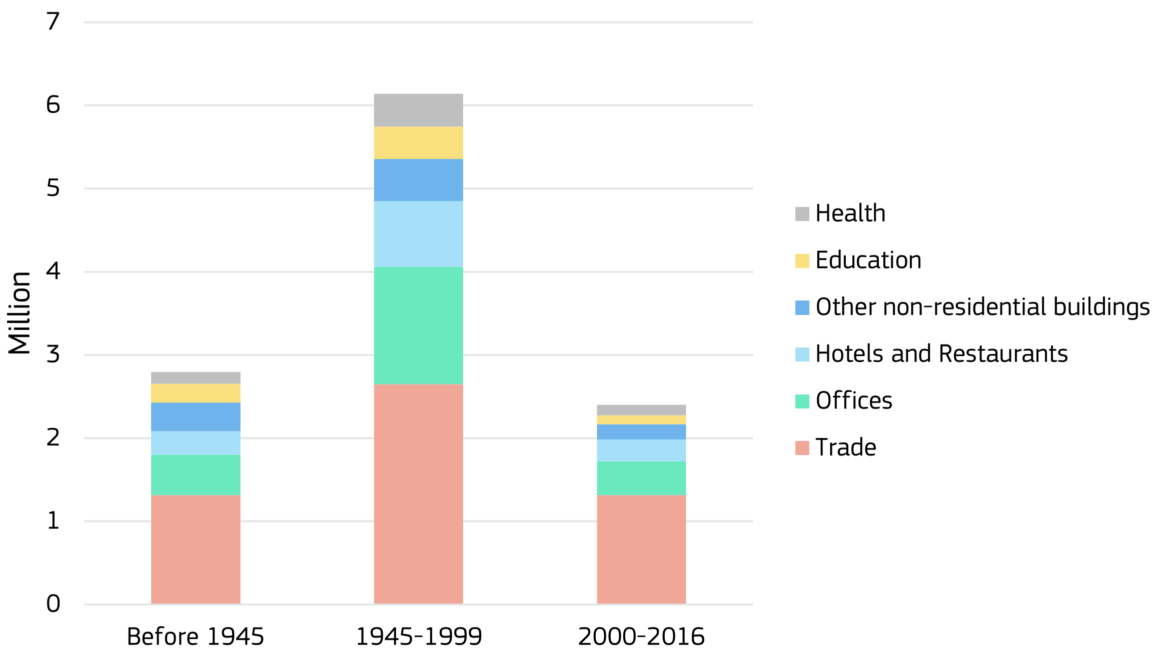


Source: JRC

3.3 Services building stock

The number of service buildings in the EU is significantly lower than that of residential buildings. There are only 12 million service-related buildings with 40 million units. As a rule, only office-related and, to some extent, trade-related buildings have more than one unit per building. As with residential buildings, around 55% of service buildings were built between 1976 and 2000. Another 25% were built before 1946. The remaining 21% were built after 2000. The majority of buildings are used for trade (47%) and as offices (20%) **Figure 16**. Moreover, these two categories account for 90% of all units (52% offices and 38% trade). Due to considerably lower numbers, shorter renovation cycles and increasing electrification in service buildings, this report will concentrate on the renovation of residential buildings. Public buildings cover, on average, around 10% of the non-residential floor area according to (European Commission, 2014).

Figure 16 Services building stock by construction period



Source: JRC based on (Hotmaps, 2021)

4 Scenario selection

The basis of comparison is the amount of CO_2 reduction, in terms of energy-related and process CO_2 (including international aviation), excluding land use, land-use change and forestry (LULUCF), which is often not covered in these scenarios. This report analyses two subsets of scenarios (Table 3), more specifically:

— Those that meet the *mid-term ambition* (i.e. emission reduction of around 55% by 2030 compared to 1990). This group includes 8 scenarios. These scenarios are in line with the ambition of the Fit for 55 impact assessment that result in GHG reductions of 53% when excluding LULUCF and 55% when including LULUCF in 2030 compared to 1990;

— Those that meet the *long-term vision* (i.e. near-zero emissions in the EU by 2050 compared to 1990). This group includes 11 scenarios. Some scenarios, like the ambitious scenario from the project Hotmaps (Hotmaps, 2021), do not reach sufficient carbon emission reduction to be included in this list.

Table 3 Scenarios that meet the mid-term ambition and/or long-term vision for emission reduction. The reduction covers energy-related and process CO_2 (including international aviation), excluding LULUCF ([a])

Nr	Publisher	Scenario abbreviation	2030	2050
1	bp	bp Net Zero	-58%	-100%
2	DNV	DNV Natural gas	-55%	-100%
3	European Commission	EC FF55 MIX	-54%	-99%
4	European Climate Foundation	ECF Demand-focus	-56%	-90%
5	EEB/CAN	EEB/CAN PAC	-76%	-100%
6	Fraunhofer ISI	Fraunhofer ISI - GHG neutral	/	-100%
7	International Energy Agency	IEA WEO SDS ([b])	-54% ([c])	-
8	Teske et al.	IFS 1.5C	-77% ([b])	-100% ([d])
9	Joint Research Centre	JRC GECO 1.5C	-54%	-94% ([e])
10	Joint Research Centre	LCEO Zero Carbon	-54%	-100%
11	Navigant	Navigant Optimised Gas	/	-100%
12	Oeko-Institut	Oeko Vision	-55%	-99%

([a]) The scenarios reviewed for 2030 and 2050 are highlighted in blue.
([b]) The latest WEO 2021 publication does not have energy consumption in buildings by fuel for the EU.
([c]) International aviation emissions based on IEA ETP 2DS.
([d]) Proportional reduction assumed for non-disclosed CO_2 emissions (i.e. international aviation, process emissions).
([e]) JRC GECO 1.5C reaches 98% reduction when including LULUCF.

Source: JRC.

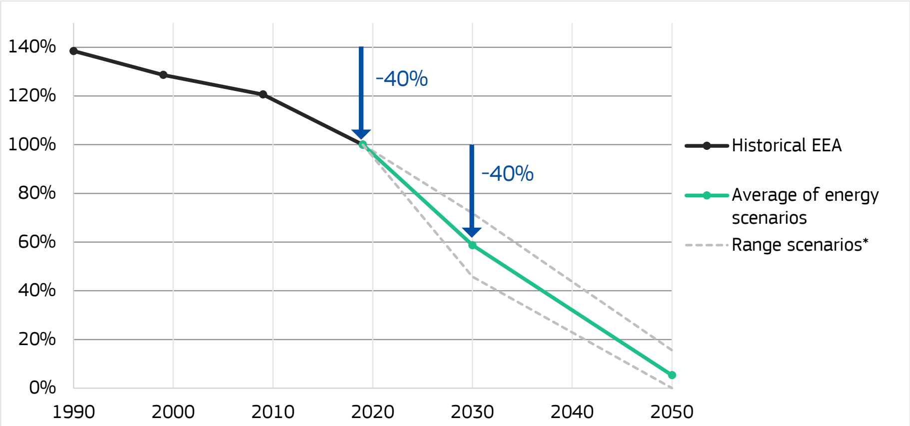
Three scenarios are from public organisations, three from private enterprises, five from research organisations (including NGOs) and one from an international organisation. The scenarios from bp, DNV, EEB/CAN, Fraunhofer and the EC FF55 MIX scenario were not covered in (Tsiropoulos, Nijs, Tarvydas, & Ruiz, 2020) because they are more recent. Although all scenarios are normative with respect to their long-term emission reduction targets (i.e. forcing emissions to decline rapidly), there are important differences in the way they seek to reach that goal, whether being cost-optimal, preferential towards specific technological options or radically diverging in other key assumptions. Most scenarios are described in (Tsiropoulos, Nijs, Tarvydas, & Ruiz, 2020) with more information on the motivation of the studies. An overview of studies and selected scenarios is in Annex 1 and an overview of the methods (models) and their scope as used in these studies is presented in Annex 2.

5 Projected fossil fuel use in buildings

5.1 CO_2 reduction as a driver

Transport, buildings, agriculture, non-ETS industry and waste account for almost 60% of total domestic EU emissions (European Commission, 2021c). When looking at the buildings sector, the carbon emission of the last 10 and 30 years was, respectively, 20% and 40% higher than 2019 emissions. The average reduction from the energy scenarios (**Figure 17**) is 40% by 2030 and 75% by 2040 when compared to 2019. Only direct emissions are covered from the energy use in buildings and not indirect emissions from the use of electricity from for example heat pumps or from district heating.

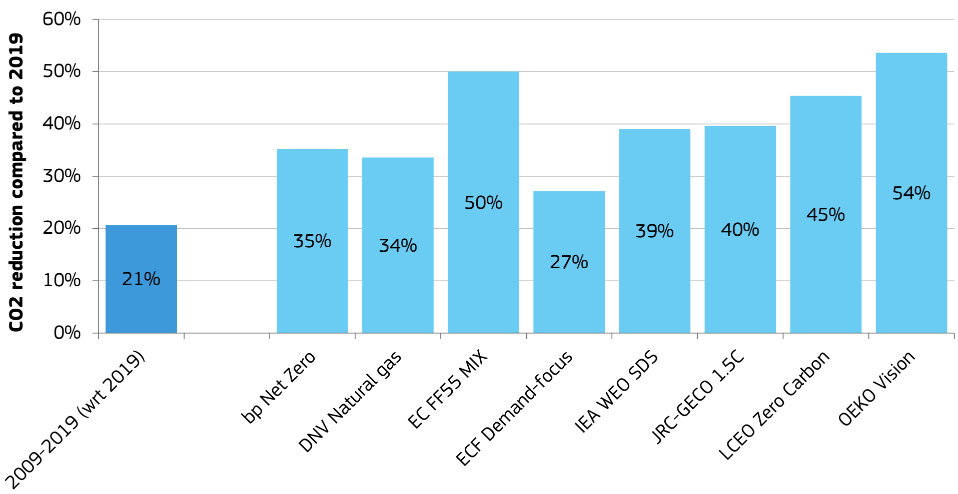
Figure 17 Historical and projected CO_2 from EU residential and services sectors based on the selected scenarios, compared to 2019.



Source: JRC.

The selected energy scenarios show a reduction of CO_2 in buildings that ranges from 27% to 54%, compared to 2019, by 2030. The data from **Figure 18** is derived from the final energy consumption of the residential and service sectors. The scenario, ECF Demand Focus, projects a more limited reduction in the buildings sector alongside a far greater reduction than other scenarios in the transport sector.

Figure 18 CO_2 reduction in buildings by 2030 compared to 2019.



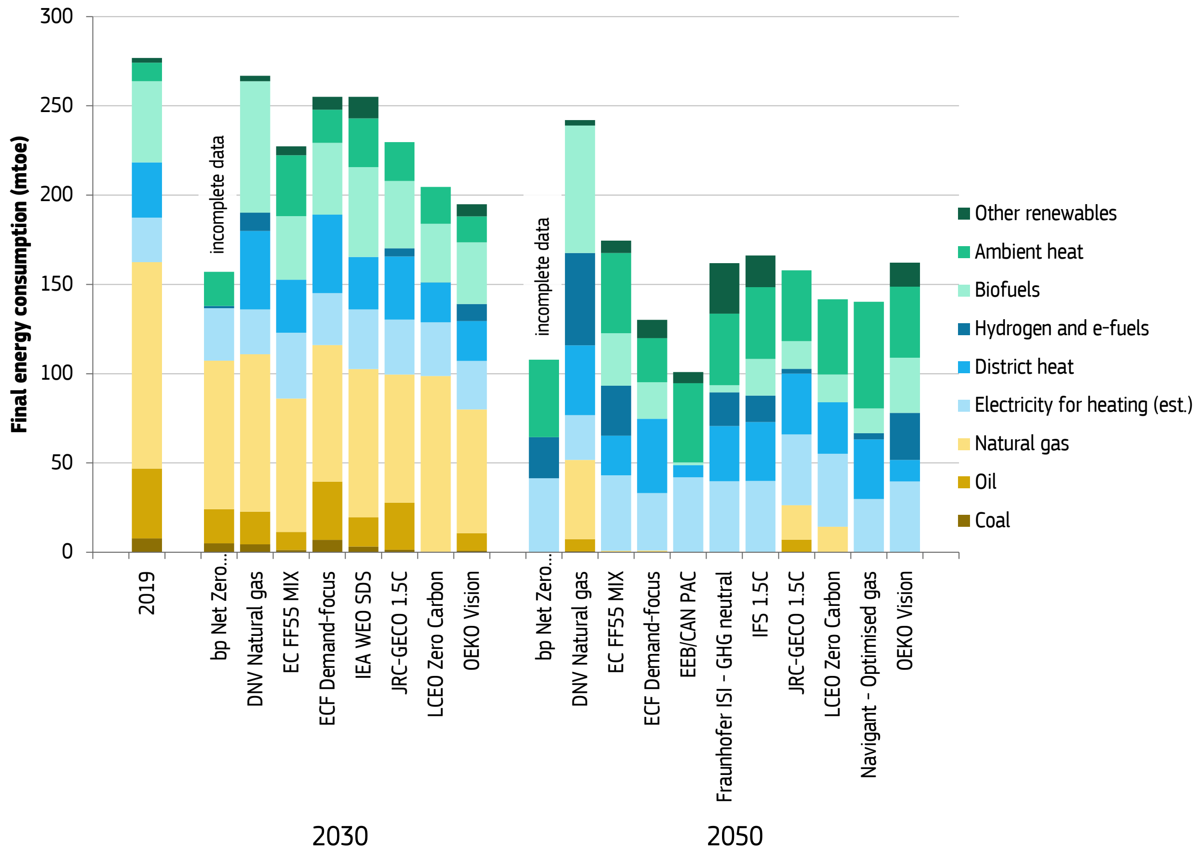
Note: Historical CO2 reduction is plotted on the left as a comparison
Source: JRC.

5.2 Towards a fossil fuel phase-out

Today, the buildings sector is highly reliant on fossil fuels, mainly providing heat. Most of this heat is used for space heating, with some for hot water preparation and cooking. **Figure 19** shows current and future use of fuels in selected scenarios. Electricity use for consumer electronics (like television or gaming consoles) or for other purposes (like lighting, washing machine or refrigerator) was excluded to represent only the electricity directly used for space heating (including electricity for heat pumps). In order to reach carbon neutrality in the buildings sector, a phase-out is needed of the fossil fuels in space heating. With very few exceptions[10], fossil fuels are used in cooking or hot water preparation only if they are also used for space heating, therefore cooking and hot water preparation is assumed to be decarbonised together with the heating system.

All scenarios analysed see a gradual phase out of the fossil fuels. In 2030, gas remains the main fuel providing heating in both residential and service buildings with a reduction of 30% in average across all scenarios. Other fossil fuels undergo even more drastic changes: direct utilisation of oil and coal in the buildings sector drops by 60% on average, in some extreme cases reaching complete phase-out by 2030 (LCOE zero carbon). These changes are triggered by policy pressure to decarbonise the economy and improving energy efficiency in building envelopes. By 2050, most of the scenarios analysed no longer see a role for fossil fuels in the buildings sector: eight out of eleven are completely fossil-free. The remaining three still see a marginal role, mainly for gas.

Figure 19 Final energy use in buildings in 2030 and 2050; for electricity, only the estimated electricity for heating is shown (no appliances, cooking or cooling).



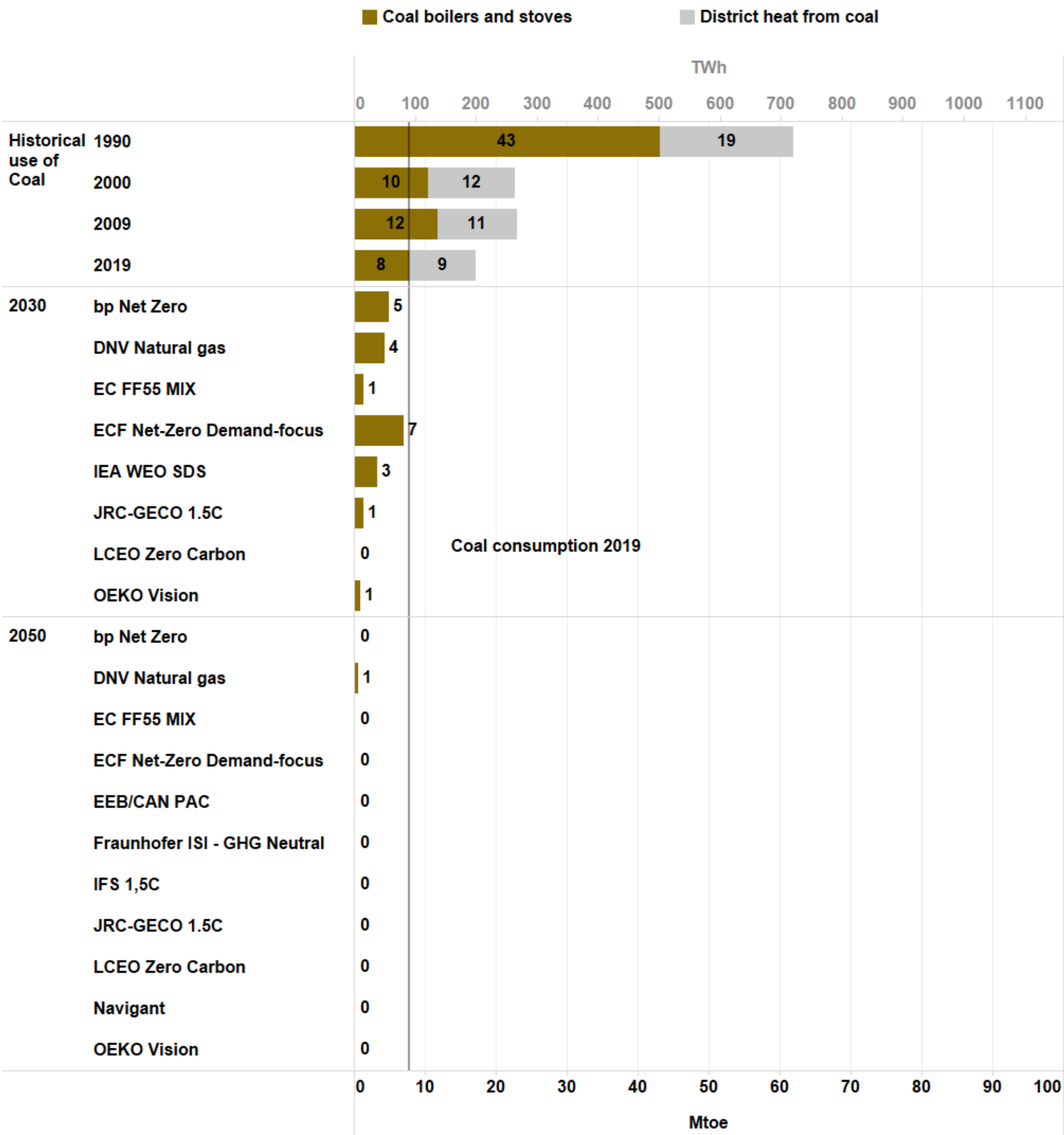
Note: Ambient heat is the heat extracted energy from the air, the ground or the water by heat pumps;
Note: bp Net-zero does not provide full energy balance for the buildings; *Source*: JRC.

[10] In rare cases natural gas may be used for cooking in multifamily buildings connected to district heating systems (mainly in the cities of new member states).

5.3 Coal use in boilers, stoves and district heating

Coal is often used in buildings located in the remote countryside or used by poor households. From the historical data it is evident that by 2019, coal was already nearly fully phased out from direct usage in the buildings sector. The same trend continues in the scenarios: in the majority of the scenarios, coal is almost phased out by 2030, driven by climate concerns and increasing demand for comfort. In 2050, all the scenarios analysed agree that there is no (or negligible amounts of) coal used in the EU building sector.

Figure 20 Historical and projected coal use for EU buildings.



Source: JRC based on Eurostat and energy scenarios described in chapter 4.

There is a 60% average reduction in coal use by 2030 compared to 2019. We use this value of 60% later in the report in the analysis of heating system renovations. As a comparison, the World Energy Outlook 2021 (IEA, 2021) has a 75% reduction of coal use for buildings by 2030, compared to 2019.

Contrary to the direct use of coal in the buildings sector, the historical decline of coal usage in district heating is not very steep. In the last decade of the last century, coal usage in district heating decreased by about

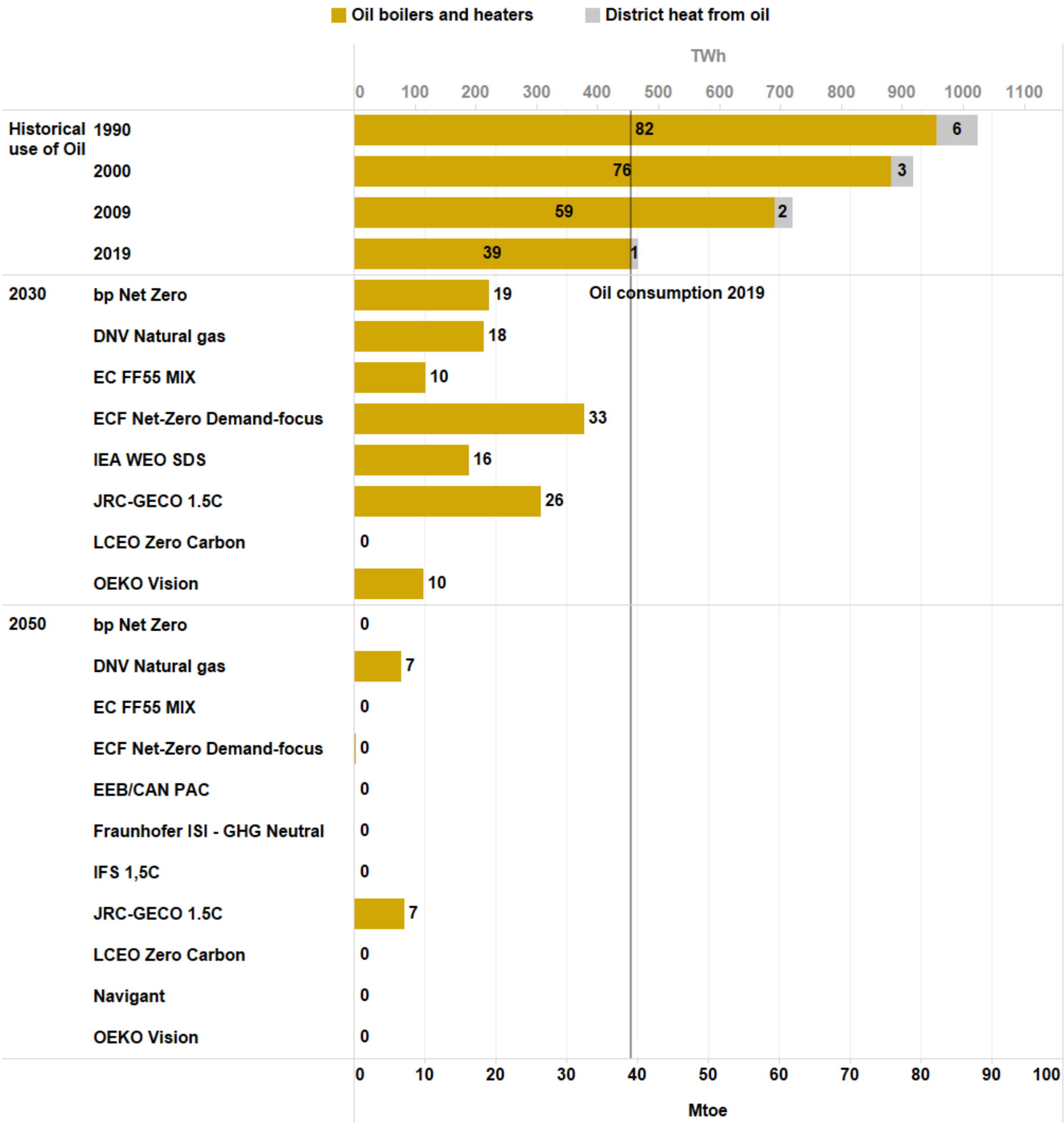
35%, and has stayed almost constant since (with the exception of a noticeable decline in 2019). This was probably caused for the most part by low fuel prices and longer equipment lifetime compared to direct coal usage in buildings. The majority of the energy scenarios analysed do not provide sufficient detail to analyse the fuel mix in district heat supply, but it is likely to follow the power generation trend (considerably reducing coal usage by 2030 and completely eliminating it by 2050).

5.4 Oil use in boilers, stoves and district heating

Oil (fuel oil or diesel) is currently the second most popular fossil fuel used in the building sector. Despite constant decline, 39 Mtoe of oil was used directly in buildings in 2019. That is a decline of just 55% compared to 1990. Scenarios do not agree on the decline of oil usage over the coming century. Although they average out at a decline of 50%, some project a decrease as low as 15% compared to today and some go as far as projecting a complete phase out of oil in the building sector by 2030.

Fuel prices and government policy play a key role in reducing direct oil usage in the buildings sector. By 2050, most scenarios see a complete phase out of oil in the sector. Contrary to the direct use of oil, the historical decline of oil usage in district heating was very steep. In 2019 it is almost non-existent, and will probably be completely eliminated by 2030.

Figure 21 Historical and projected oil use for EU buildings.



Source: JRC based on Eurostat and energy scenarios described in chapter 4.

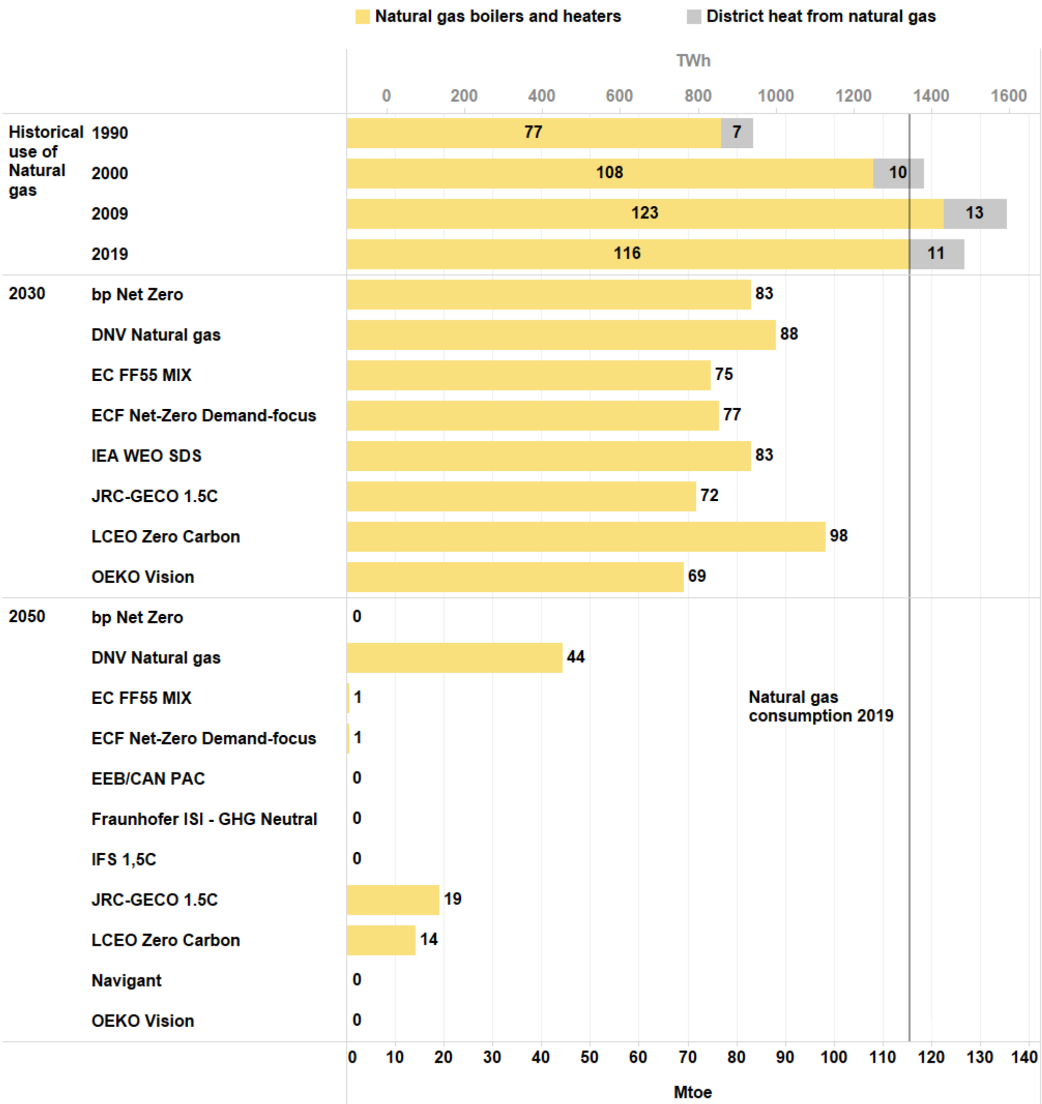
5.5 Natural gas use in boilers and district heating

Direct consumption of natural gas in the buildings sector increased gradually from 77 MTOE in 1990 to 116 MTOE in 2019. This was caused by two main drivers: until recently, natural gas used to be one of more convenient fuels for decentralised heating, replacing coal and oil boilers and taking a noticeable share of new construction. Only since 2017 can a downwards trend be observed.

In the scenarios analysed, natural gas remains one of the most important energy sources for buildings (after electricity) in 2030. All high decarbonisation scenarios see a reduction in gas consumption, with rates varying from 15% to 45% in 2030. The average reduction works out as 30% compared to 2019 values. We use this value of 30% later in the report in the analysis of heating system renovations. As a comparison, the World Energy Outlook 2021 (IEA, 2021) has a 36% reduction of natural gas use for buildings by 2030, also compared to 2019.

In some scenarios, natural gas acts as a transition fuel, reducing CO_2 in the short term by replacing more carbon intensive fuels. In others, it is reduced more rapidly via faster decarbonisation of heating and a faster improvement in the energy efficiency of building shells.

Figure 22 Historical and projected natural gas use for EU buildings.



Source: JRC based on Eurostat and energy scenarios described in chapter 4.

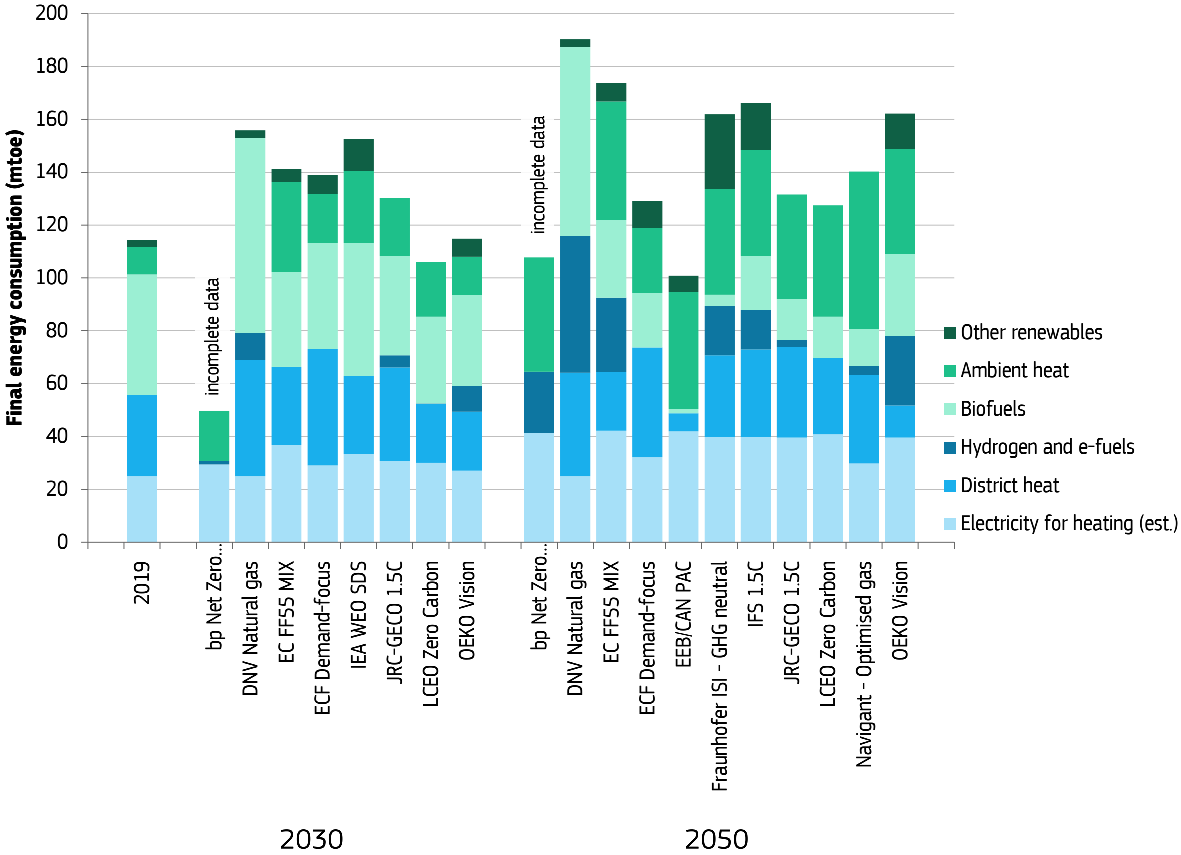
By 2050, most of the scenarios see a complete phase-out of gas in the buildings sector. In other cases, natural gas consumption remains as high as 44 Mtoe. There are several factors keeping natural gas in the buildings energy mix. One of most important is infrastructure cost. Natural gas emissions are largely offset by CCS/U technologies in other sectors – mainly power generation and industry.

Until around 2010, natural gas consumption was rising gradually in district heating, mainly by replacing the more expensive oil, but in the last decade it has been pushed out by increasing shares of biomass and waste.

6 Projected non-fossil fuel energy use in buildings

This chapter aims to present the impact of drastic changes in the buildings sector on energy use from non-fossil fuel sources, covering biofuels, ambient heat, district heat, electricity, hydrogen (including e-fuels) and other renewables. Driven by various decarbonisation pathways and socio-economic assumptions, scenarios foresee various roles for non-fossil energy in heating and cooling **Figure 23**. In 2030, the role of non-fossil fuel energy in buildings is similar to today: three out of seven scenarios foresee a small decrease, and four predict an increase of up to 15%. In 2050, the situation is different: three scenarios foresee a similar and seven scenarios an increased absolute amount. This results in an increased share of non-fossil energy use in all scenarios.

Figure 23 Non-fossil final energy use in buildings in 2030 and 2050; for electricity, only the estimated electricity for heating is shown (no appliances, cooking or cooling).



Note: bp Net-zero does not provide full energy balance for the buildings; *Source*: JRC.

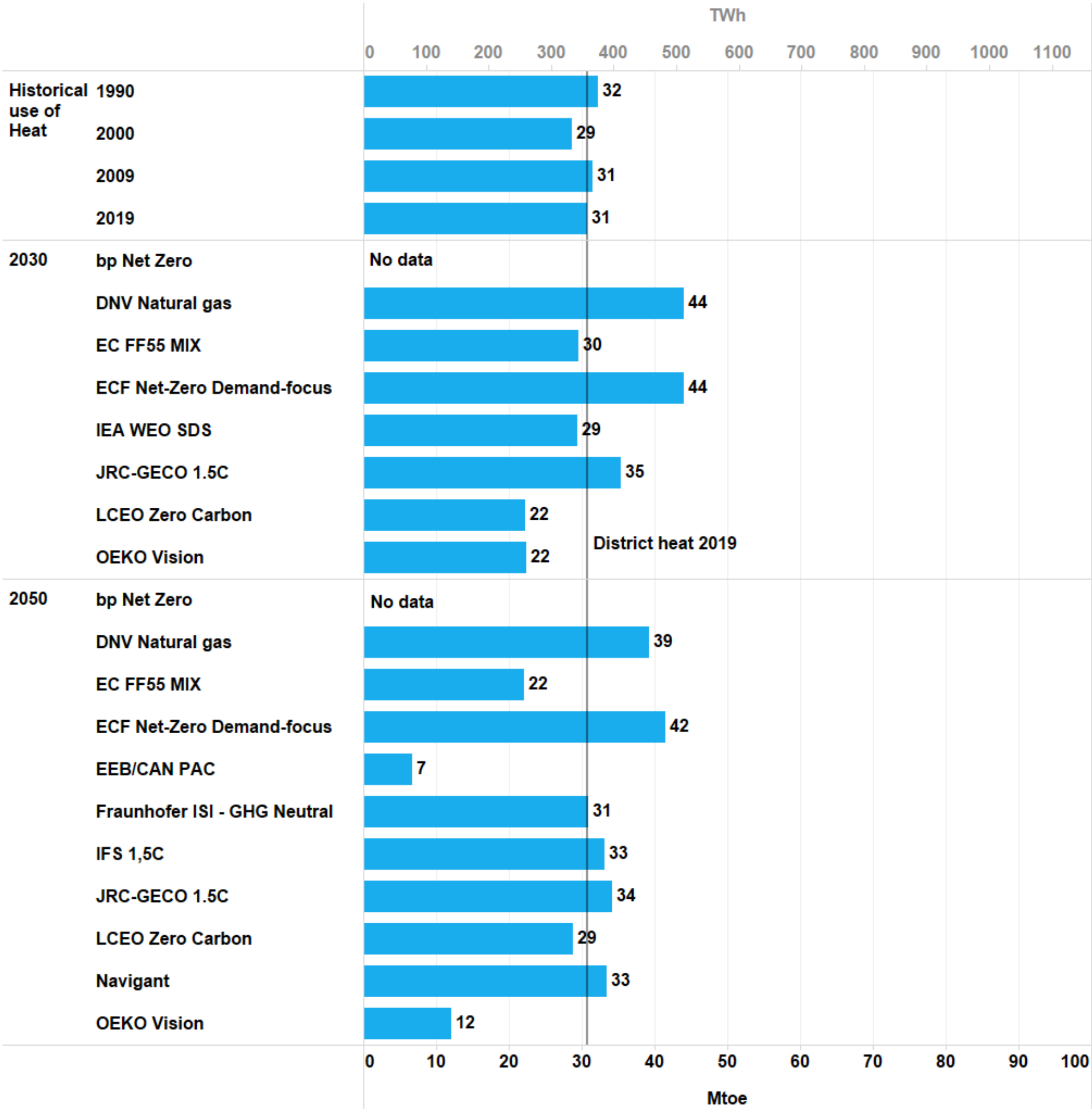
Electricity for heating increases in all scenarios. On average, across scenarios, the increase is 21% by 2030 and 52% by 2050. The share of electricity for heating is in most scenarios around a third. When we also include ambient heat, the share is around two thirds.

For the buildings sector, the report only covers biomass total energy use and RFNBOs. There is not sufficient data to distinguish fuels from biogas or advanced biofuels.

6.1 District heat

Over the years, the scale of district heating in the EU has remained quite constant with a small fluctuation of around 31 Mtoe, mainly influenced by outside temperatures. New connections to district heating systems, mainly in Scandinavian countries, are offset by increasing energy efficiency in the building shell and some minor disconnections from former Soviet countries. As discussed in previous chapters, the fuel mix of the heating sector has changed, with natural gas gradually replacing oil, and in more recent years, biomass replacing natural gas and coal. From the energy scenarios, we do not have sufficient details to know the share of efficient district heating in line with EU policy as described in chapter 9.

Figure 24 Historical and projected district heat use for buildings.



Source: JRC based on Eurostat and energy scenarios described in chapter 4.

In 2030, all the scenarios analysed acknowledge the role of district heating in the buildings sector, but disagree on its importance. Some scenarios keep district heating at a relatively similar level (such as EC FF55 MIX). Others foresee increases of up to 40% and others see declines of more than 30%. There are several factors affecting the attractiveness of district heating in the scenario studies. For example, increased efficiency and electrification (using industrial scale heat pumps) reduces the attractiveness of district heating. Expensive infrastructure also reduces possible penetration. But on the other hand, it is easier (and cheaper) to decarbonise centrally produced heat than to address individual heating. District heating also creates opportunities utilising waste heat.

Scenarios that recognise the growth potential of district heating for 2030 also give it more prominence in 2050. However, all scenarios see a decline in demand for district heating by 2050 (relative to the values given for 2030). The main driving factors are improvements in the energy efficiency of the building shell (reducing demand in dwellings already connected) and the complexity of building new district heating networks, especially in densely populated areas.

6.2 Hydrogen and e-fuels

Historically, hydrogen and other e-fuels were not used in buildings either directly or indirectly. In 2030, energy scenarios do not see a role for hydrogen or e-fuels in the buildings sector, except three that have a limited uptake, comparable with today's usage of coal.

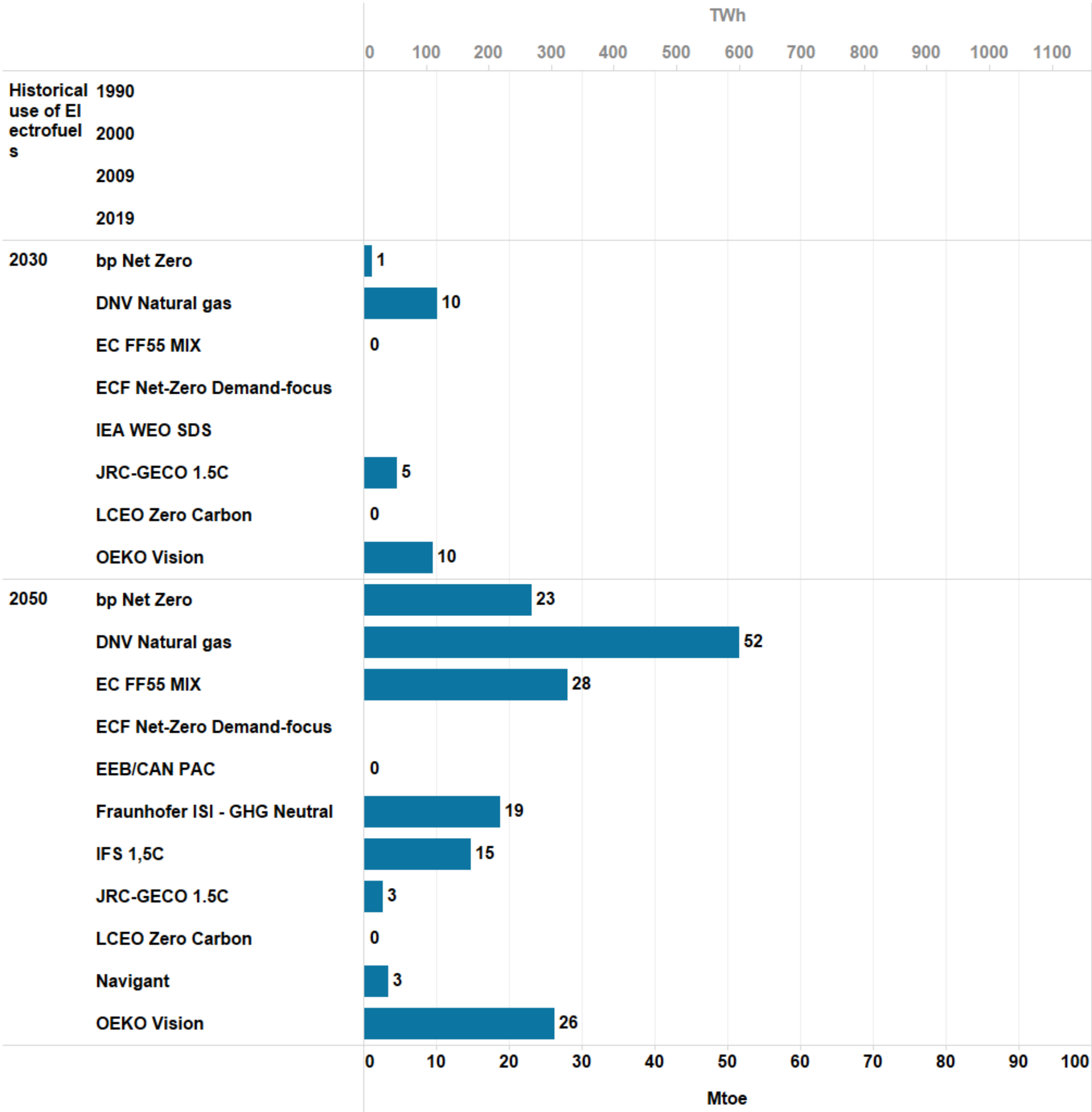
In the Impact Assessment (European Commission, 2021h) for the revision of the Renewable Energy Directive (RED), renewable fuels of non-biological origin (RFNBOs) and innovative low-carbon fuels are explicitly addressed. It is stated that hydrogen produced from electricity and its derivatives (so-called "e-fuels") can particularly offer solutions to decarbonise the economy in sectors where electrification is unfeasible, inefficient or more expensive.

However by 2030, there is no uptake of hydrogen in the buildings sector, even in the variant MIX-H2. In MIX-H2, renewable hydrogen and hydrogen-based synthetic fuels sourced from renewable energy represent 2.6% of fuels consumed in all transport modes. It is mentioned in (European Commission, 2021h) that for heating and cooling, other renewable alternatives for the building and the industrial sectors remain more competitive than RFNBOs. Among other issues, the high conversion losses during the production of RFNBOs (conversion efficiency of 70% for hydrogen via electrolysis and about 50% for further processing into liquid RFNBOs) play an important role.

By 2050, the situation is different. Five of the eleven scenarios foresee a limited role for hydrogen or e-fuels in the buildings energy mix. In these scenarios, the preferred option is direct electrification, predominantly with efficient heat pumps. However, even scenarios that do see hydrogen and e-fuels catching on do not agree about its importance. At the lower end, some scenarios like GECO 1.5 predict just 3 Mtoe (still relying largely on direct electrification). At the higher end, the DNV scenario gives synthetic fuels, driven by the benefits of a pre-existing gas infrastructure, a major role.

In 2050 FF55 MIX, the deployment of renewable and low-carbon gases (mostly e-gas) aid the switch away from fossil fuels. In buildings, hydrogen and e-gas make up 10% of final energy consumption (European Commission, 2021b).

Figure 25 Historical and projected hydrogen and e-fuels use for EU buildings.



Source: JRC based on Eurostat and energy scenarios described in chapter 4.

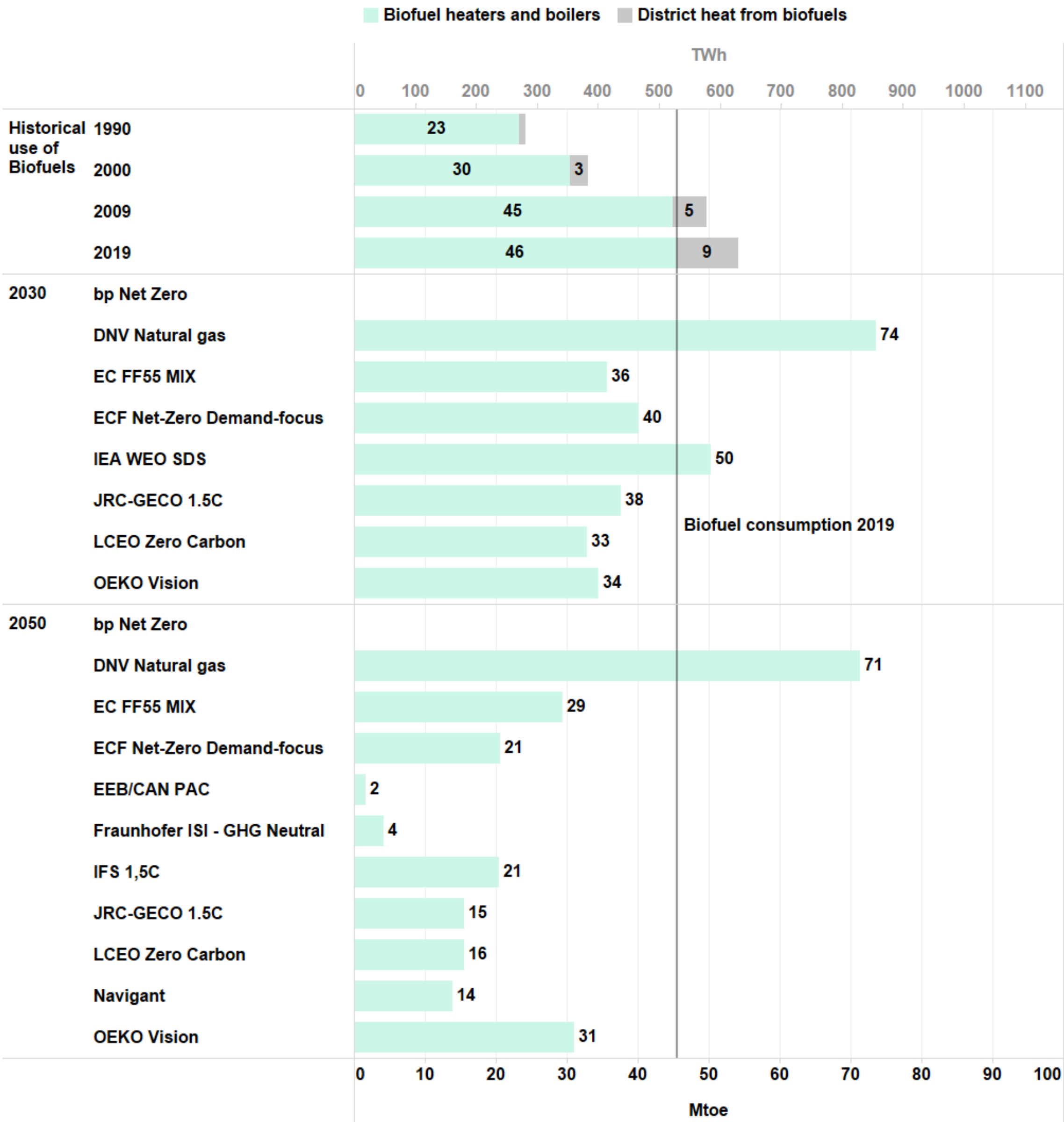
6.3 Biofuel

Historically, biofuels have played an important role in the buildings sector, especially in the residential sector. In 2019, solid biofuels covered about 17% of total final demand in the EU's residential sector. The majority of biofuel was used for heating (24% of heating demand was covered by solid biomass). In the services sector, the role of solid biomass was less prominent: only 2.4% of final energy was covered by biomass. Current trends do not show any increase in biofuel consumption in the buildings sector.

On top of direct use, biofuels are also used to generate district heat. Since 2000, the share of biofuels in district heating has gradually increased, in some countries covering more than 50% of commercial heat demand, but in the last few years the growth has exhausted itself.

Most of the scenarios do not provide data on the fuel mix of district heating. The IFS scenario shows an upwards trend in biofuel usage in commercial heat production, with a downward trend for the HOB scenario and upward trend for CHP. Most of the scenarios see a downward trend in the use of biofuels in the buildings sector, decreasing by 10% on average by 2050, and 45% by 2050. Only one scenario (DNV-Navigant) sees a persistent increasing reliance on biofuels. There is general disagreement among studies on the rate of reduction. In seven out of 11 cases there is only a slight reduction (comparable to the building renovation effect), and in two other cases biofuels disappear almost completely from direct use in buildings. We do not know the drivers of the energy scenarios. However, elements that may play a role are: an increase in comfort demand (the utilisation of other alternatives is less labour-intensive); the higher efficacy of other heating options (mainly heat pumps); the fact that other uses of biomass and biofuels create more value added compared to direct use in buildings; and considerations about air pollutant emissions.

Figure 26 Historical and projected biofuel use for EU buildings.



Source: JRC based on Eurostat and energy scenarios described in chapter 4.

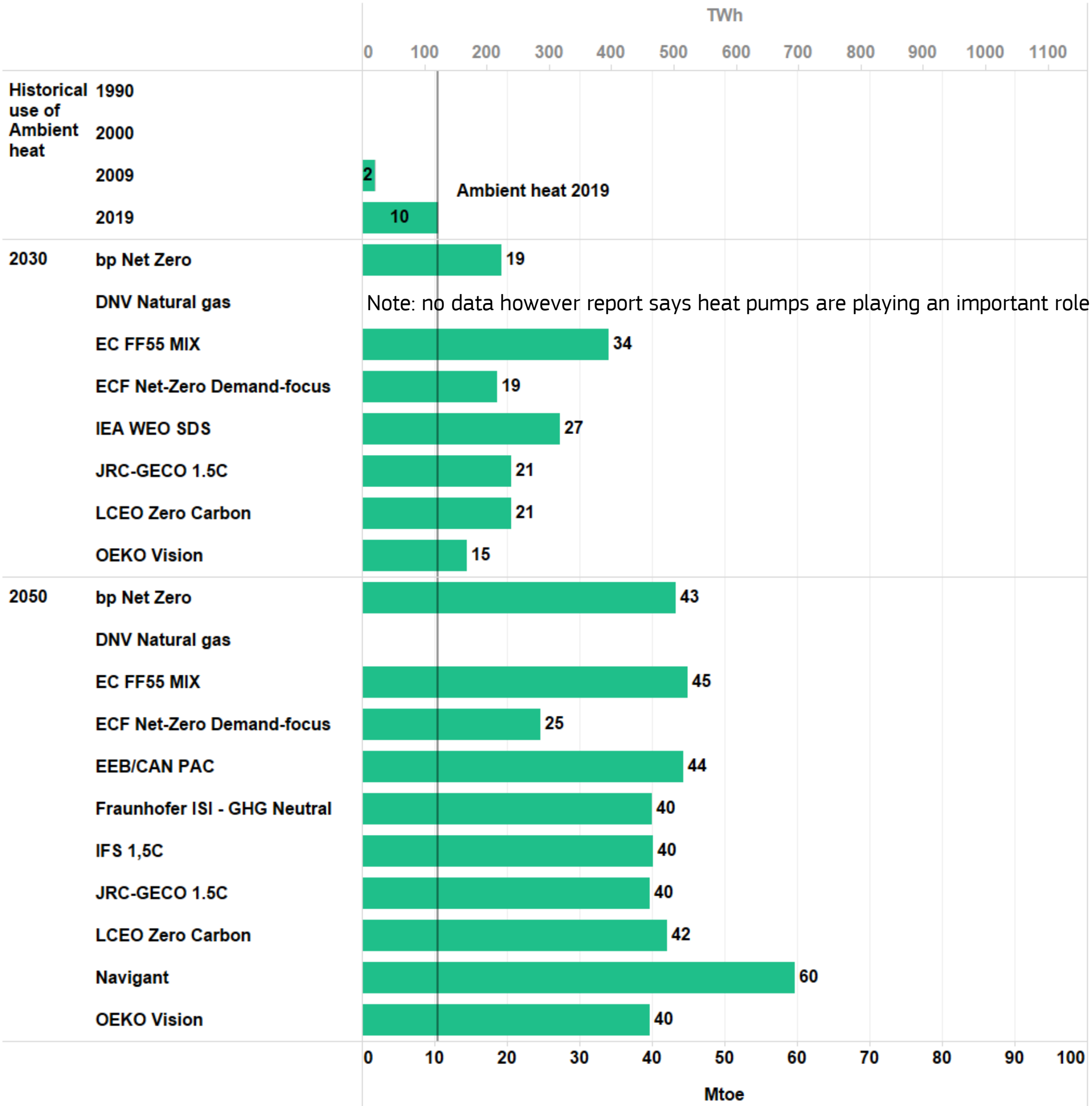
6.4 Heat pumps

Historically, heat pumps only started to take off in the buildings sector during the last decade[11]. In 2009 there was only 2 Mtoe of ambient heat used in the buildings sector, but in 2019 it increased five-fold to 10 Mtoe. Most scenarios see a continuation of this trend.

In 2030, all scenarios see an increase in ambient heat demand, from a modest 50% increase in the OEKO Vision scenario, to a tripling in the EC FF55 MIX.

In 2050, ambient heat becomes one of the main energy sources for heating and hot water preparation, providing on average at least 40 Mtoe across all scenarios.

Figure 27 Historical and projected use of ambient heat for EU buildings.



Source: JRC based on Eurostat and energy scenarios described in chapter 4.

[11] In some countries heat pumps started to play a noticeable role in the buildings sector earlier. For example sales of ground-based heat pumps reached 25 000 in Sweden in 1990 (Karlsson, Axel, & Fahlen, 2003).

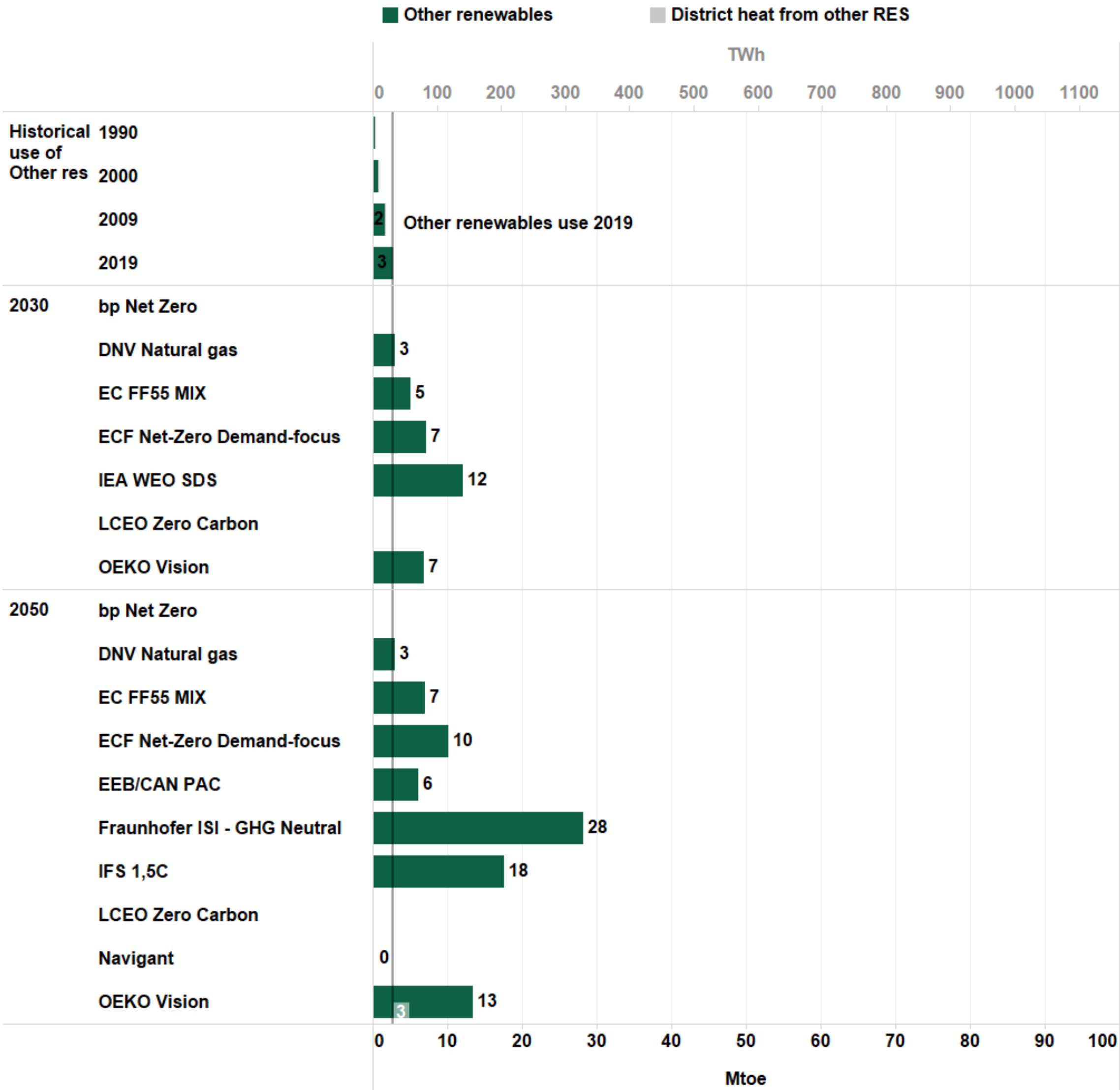
6.5 Other renewables

Other renewables (mainly solar thermal) do not play a significant role in buildings. In 2030, most of the scenarios analysed see an increase of solar thermal combined with shallow geothermal that quadruples in the case of IEA WEO.

In 2050, the growth continues, but despite a strong increase in some of the scenarios (up to tenfold compared to 2019 in Fraunhofer ISI), it covers less than 10% of final energy demand in the buildings sector. In most of the remaining studies, other renewables cover around 3% of final energy demand.

For energy statistics, PV in buildings belong to decentralised electricity generation, not the buildings sector. From the scenario results, the role of PV in building is unclear. Comparing the relative performance of PV and solar thermal is out of scope of this report. A JRC paper (Katalin, Ioannis, Arnulf, Nigel, & Sandor, 2019) shows however that EU rooftops could potentially produce 680 TWh of solar electricity annually (representing 24.4% of current electricity consumption).

Figure 28 Historical and projected use of other renewables for EU buildings.



Source: JRC based on Eurostat and energy scenarios described in chapter 4.

7 Scaling up renovations in residential buildings

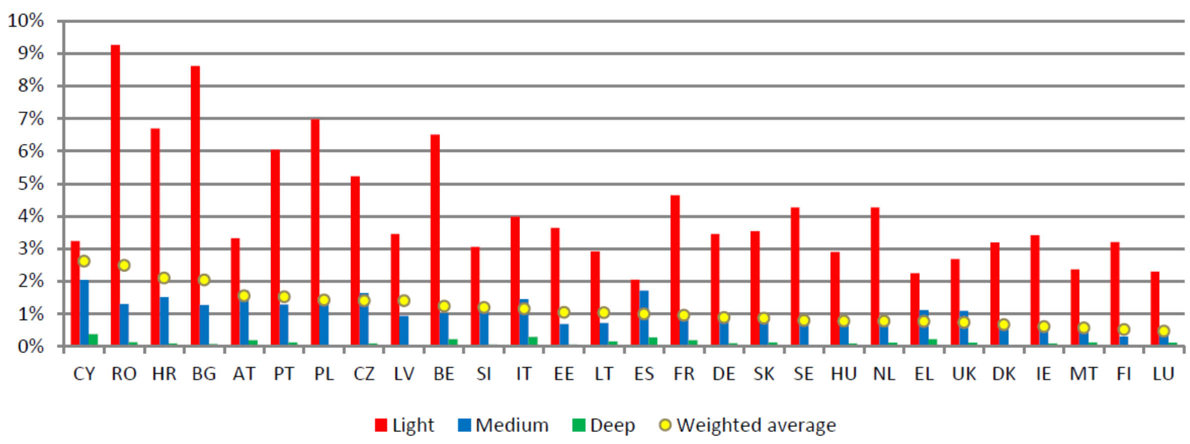
In this chapter we analyse our own renovation scenarios, made in line with the reductions shown in the energy scenarios in Chapter 5. After presenting the methodology in section 7.1, we describe the scale-up of envelope renovations in section 7.2, and of heating system renovations in section 7.3. The chapter concludes with an overview of both energy and heating system renovations in section 7.4. Residential dwellings are the focus of this chapter because around 90% of the building stock consists of residential buildings (Hotmaps, 2021).

7.1 Methodology

In this section we explain the approach we took to estimate the number of renovations by type and the number of dwellings with low-carbon heating systems. The energy scenario studies discussed in the previous chapter often do not have or do not report information on the number of buildings that switch fuels. However, those numbers can be derived by combining data on energy demand and on energy efficiency levels of buildings. It is also often the case that energy scenarios offer no information on insulation levels, so we estimate those based on our own renovation scenarios. The following approach is used to estimate the required switch away from fossil heating systems:

- The starting point is the average reduction of fossil fuel use from a wide range of **energy scenarios** that achieve around 55% reduction of greenhouse gas emissions by 2030 compared to 1990, and aim at climate neutrality by 2050.
- We created a simplified **building envelope renovation model** to better understand the impact of building shell renovation on energy use in buildings and its possible impact on fossil fuel use. The model estimates the heat demand based on information on building stock ((Hotmaps, 2021), (European Commission, 2019)) and renovation rates and depths (**Table 4**). The majority of energy in the buildings sector (both services and residential) is used for heating and cooling. Therefore, the renovation of the building shell by increasing thermal resistance following the adoption of new building codes, moving towards nearly zero-energy buildings, is an essential component of the sector decarbonisation pathway. The majority of renovations have little to do with energy conservation (Ipsos Belgium/Navigant, 2019) despite a rapid building renovation pace in the EU (over 12% in residential and almost 10% in services in 2012-2016). More than half of these renovations were either not related to energy or could be classified as light. Only 0.2% of residential buildings and 0.3% of service buildings underwent a deep energy-related renovation in this period. According to most energy scenarios, deep renovation rates should increase at least tenfold in order to reach climate neutrality. Up to 2030, medium and deep renovation rates could reach around 2% (European Commission, 2021f), and around 4% per year for deep renovations in very ambitious scenarios (European Climate Foundation, 2018).

Figure 29 Renovation rates in residential buildings in the EU + UK by renovation level, annual average 2012-2016.



Source: (Zangheri, et al., 2021)

The key assumptions underpinning this building envelope renovation model are outlined below.

- We assume an annual envelope renovation rate of 2.5%. The current annual envelope renovation rate amounts to 1.3% when including medium and deep renovation. This is a percentage of the 2019 stock, not the average primary energy reduction which is lower than 1%. See also (Zangheri, et al., 2021).
- The envelope renovation can only gradually increase from its current value of 1.3%. We assume that the rate increases during the first four years (2022-2025) and there is therefore a need for a higher renovation rate in the period 2026-2030 if we are to reach an average 2.5% in the period 2022-2030. In the period 2026-2030, the envelope renovation rate is minimum 2.7%.
- We use historical information from (Eurostat, 2021), (Hotmaps, 2021) and (Mantzos, et al., 2018).
- Due to climate change, we assume a constant reduction of heating demand by 0.1% per year.
- Our assumptions on yearly renovation rates and depth is provided in Table 4. Our assumptions are on the high side compared to the EC FF55 MIX scenario, therefore we assume it represents a maximum realistically possible reduction of energy consumption in buildings due to building shell renovation. Different scenario studies use slightly different definitions of renovation depth, but there is a common understanding that deep renovation should reduce building energy demand for heating and cooling by more than 60% (Kruit, Vendrik, Berkel, Poll, & Rooijers, 2020). In some extreme cases, scenarios use a high 90% reduction of energy demand for heating and cooling in renovated buildings[12] (European Climate Foundation, 2018). Renovation resulting in an energy reduction of less than 30% is considered light renovation and everything in between is defined as medium. These assumptions are in line with (The European Comission, 2019).

Table 4 Assumed yearly renovation rates and depth for all buildings envelope (model input for all renovation scenarios)[13]

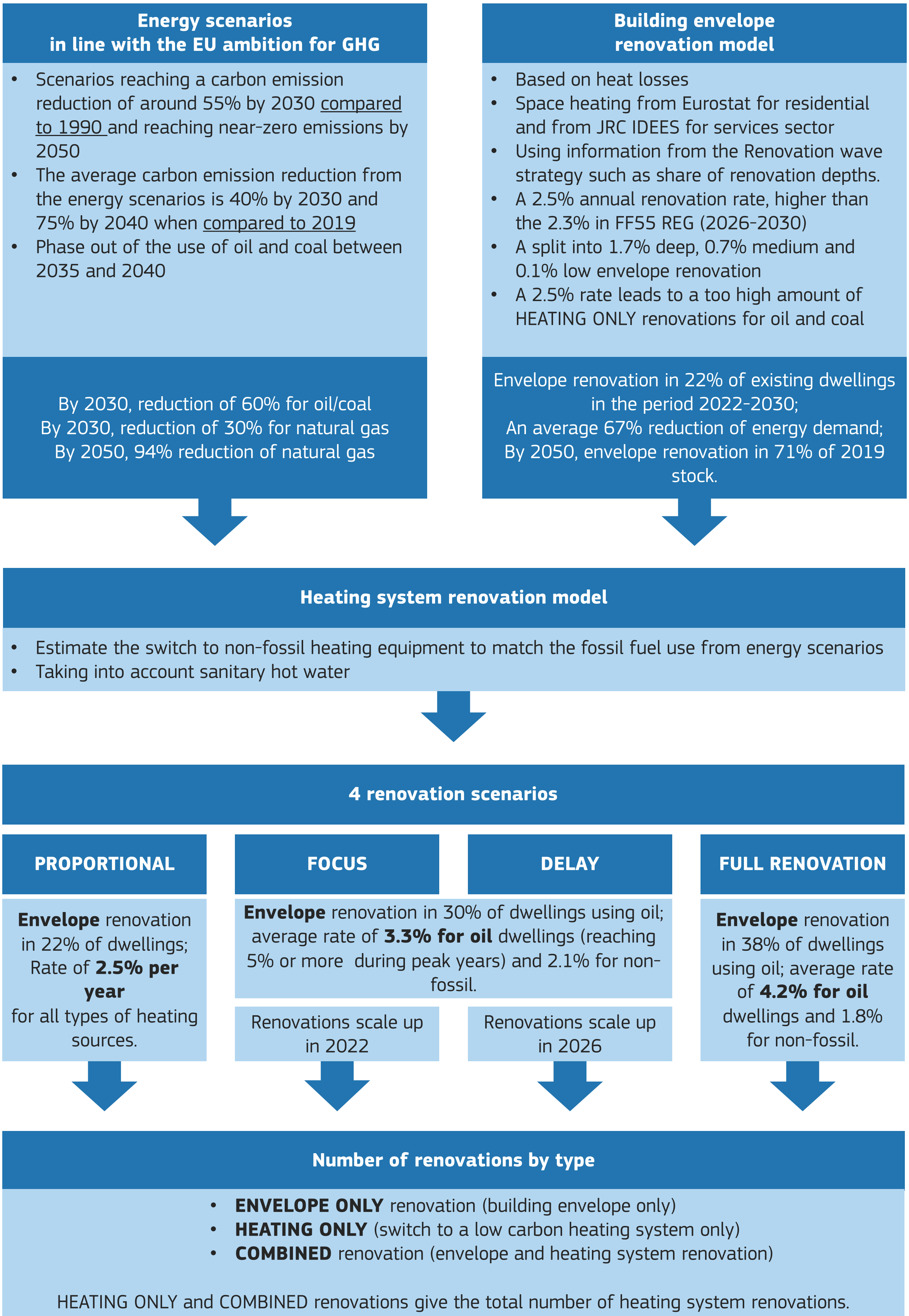
	Constant rates throughout 2022-2050	
	Depth	**Rate**
Low	20%	0.14%
Medium	45%	0.66%
Deep	80%	1.65%

Source: JRC.

[12] Probably only a small share of buildings could reach 90% reduction in heating and cooling energy consumption, because it essentially requires a drastic increase in the thermal resistance of all elements of the building (foundation, floors, walls, windows, roof) and additional engineering solutions like heat recovery using recuperation. Moreover, there is a considerable share of buildings that will never undergo deep shell renovations. These include heritage and other historical buildings and low value buildings.

[13] In this context depth means energy saving after the envelope renovation, and rate means share of dwellings renovated per year (from existing building stock in 2019). In one year, 0.14% of existing stock will be renovated with low depth (20%), 0.66% will be renovated with medium depth (45%) and another 1.65% will be renovated with 80% depth.

Figure 30 Overview of methodology.



Source: JRC.

— Using this building envelope renovation model, we created **four renovation scenarios** that assume a gradual uptake of envelope renovations to a level of 2.5% of the dwelling stock. For residential buildings, this is double the renovation rate as projected in the Reference Scenario (European Commission, 2021d) in the period 2026-2030. We deliberately chose high renovation rates to estimate the minimum need for low-carbon heating systems, even when strong insulation efforts are made. We define four renovation scenarios:

1. **PROPORTIONAL**: efficiency efforts are evenly distributed among all types of dwellings;
2. **FOCUS**: increased efficiency for dwellings currently on oil or coal (3.3%). In the PROPORTIONAL scenario, too many dwellings switch fuel without a renovation of the building envelope. It is uneconomic (and not energy efficient) to do a fuel switch first and insulate afterwards;
3. **FULL RENOVATION**: for oil, an even higher rate for envelope renovations (4.2%) is assumed. For gas, no more ENVELOPE ONLY renovation;
4. **DELAYED**: renovations scale up only in 2026, rather than in 2022.

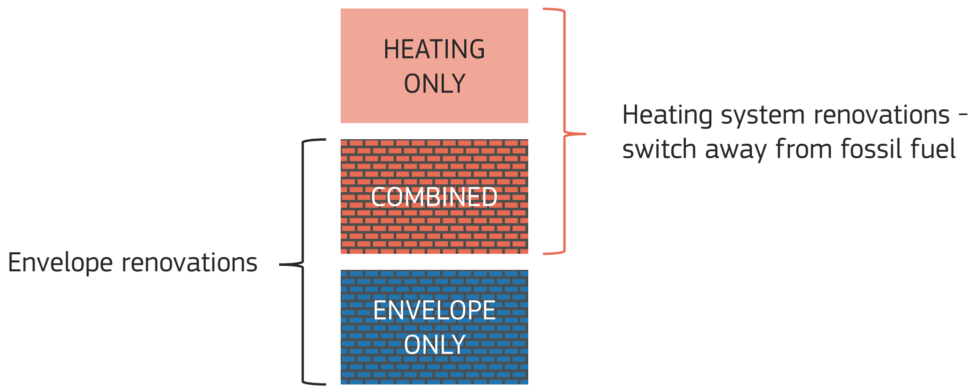
— We use a **heating system renovation model** that estimates current heating systems based on (Eurostat, 2021), (Hotmaps, 2021) and (Mantzos, et al., 2018). We estimate the switch to non-fossil heating equipment that, combined with envelope renovations, will reach the projected reductions of oil and gas use in the energy scenarios, taking into account sanitary hot water. The model is based on:

$$Fossil\ fuel\ reduction = COMB + HEATING_{ONLY} + ENVELOPE_{ONLY} * DEPTH * SpaceHeatShare$$

— We define three types of renovation. The sum of ENVELOPE ONLY and COMBINED renovations gives the total envelope renovations. The sum of HEATING ONLY and COMBINED renovations gives the total heating system renovations.

1. **ENVELOPE ONLY** renovation: building envelope without changing energy source.
2. **HEATING ONLY**: switch to a low-carbon heating system without major envelope renovation.
3. **COMBINED** renovation: a combination of building envelope and switching away from fossil.

Figure 31 Definitions of renovations used in this report.



Source: JRC.

7.2 Scaling up envelope renovations

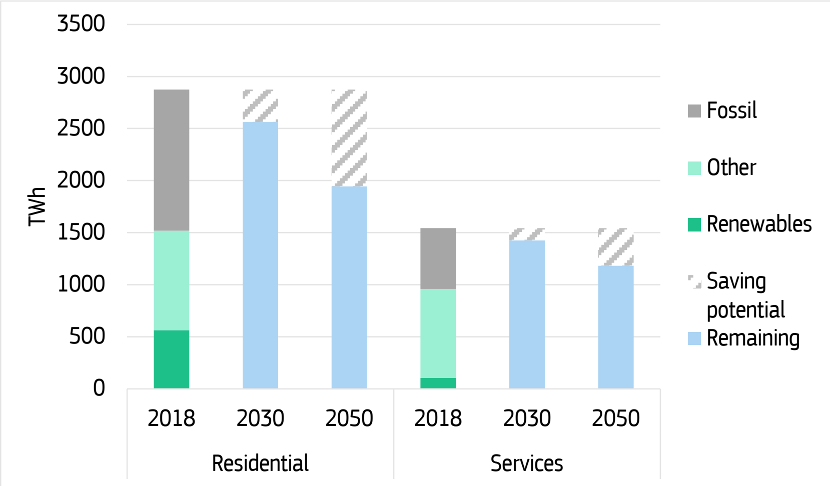
In the next two sections we describe how much energy can be saved by thermal integrity improvements of existing dwellings and what future envelope renovations could look like.

7.2.1 Energy savings from envelope renovations

Taking into account our own assumptions on buildings envelope renovation, heating demand in the buildings sector could be reduced by 16% in 2030 and reach 50% in 2050. This reduction means that, just based on building shell renovation, the energy consumption in buildings will be reduced by 429 TWh in 2030 and by

1290 TWh in 2050. **Figure 32** shows that in 2030 (based on rate and depth of envelope renovations in **Table 4**) the savings potential is equal to 11% of the final energy used in residential and 8% in service buildings. In 2050, the total amount of energy conserved in the buildings sector could be roughly equivalent to today's fossil fuel use, but that does not mean that climate neutrality could be achieved just by increasing the energy performance of the building envelope. Without switching to a different energy source, even fully renovated fossil fuel-based buildings will consume around 20%-50% of their original fossil consumption for heating, hot water preparation and cooking. Even near-zero buildings still need energy for these purposes.

Figure 32 Comparison of fossil fuel usage in EU buildings with savings potential due to building shell renovation

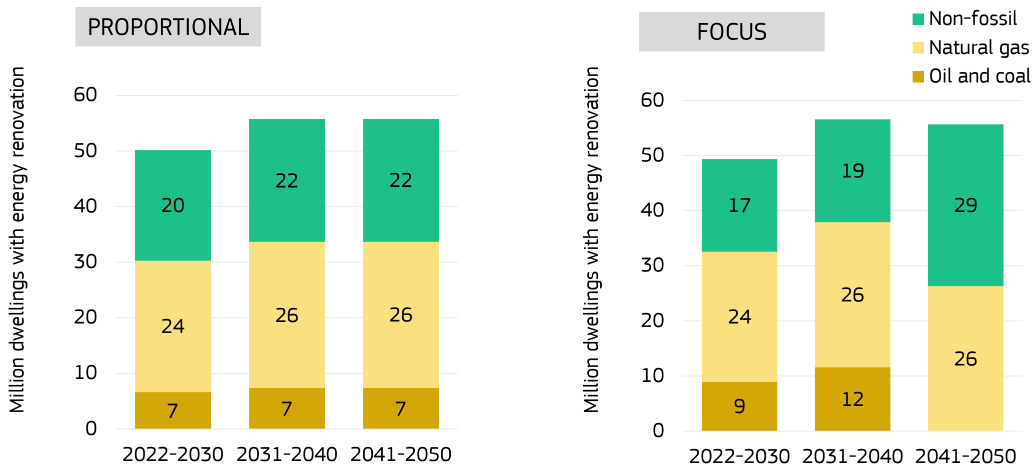


Source: JRC.

7.2.2 The future of ENVELOPE ONLY and COMBINED renovations

Depending on the renovation scenario, we assume slightly higher (lower) envelope renovations carried out in dwellings supplied by non-fossil fuels and slightly lower (higher) in dwellings supplied by fossil (**Figure 33**). In the FOCUS scenario we deliberately increase efforts in dwellings currently on oil to make it easier to decarbonise those dwellings. The 2.5% assumption then translates to around 55 million of the 230 million dwellings that are renovated every decade.

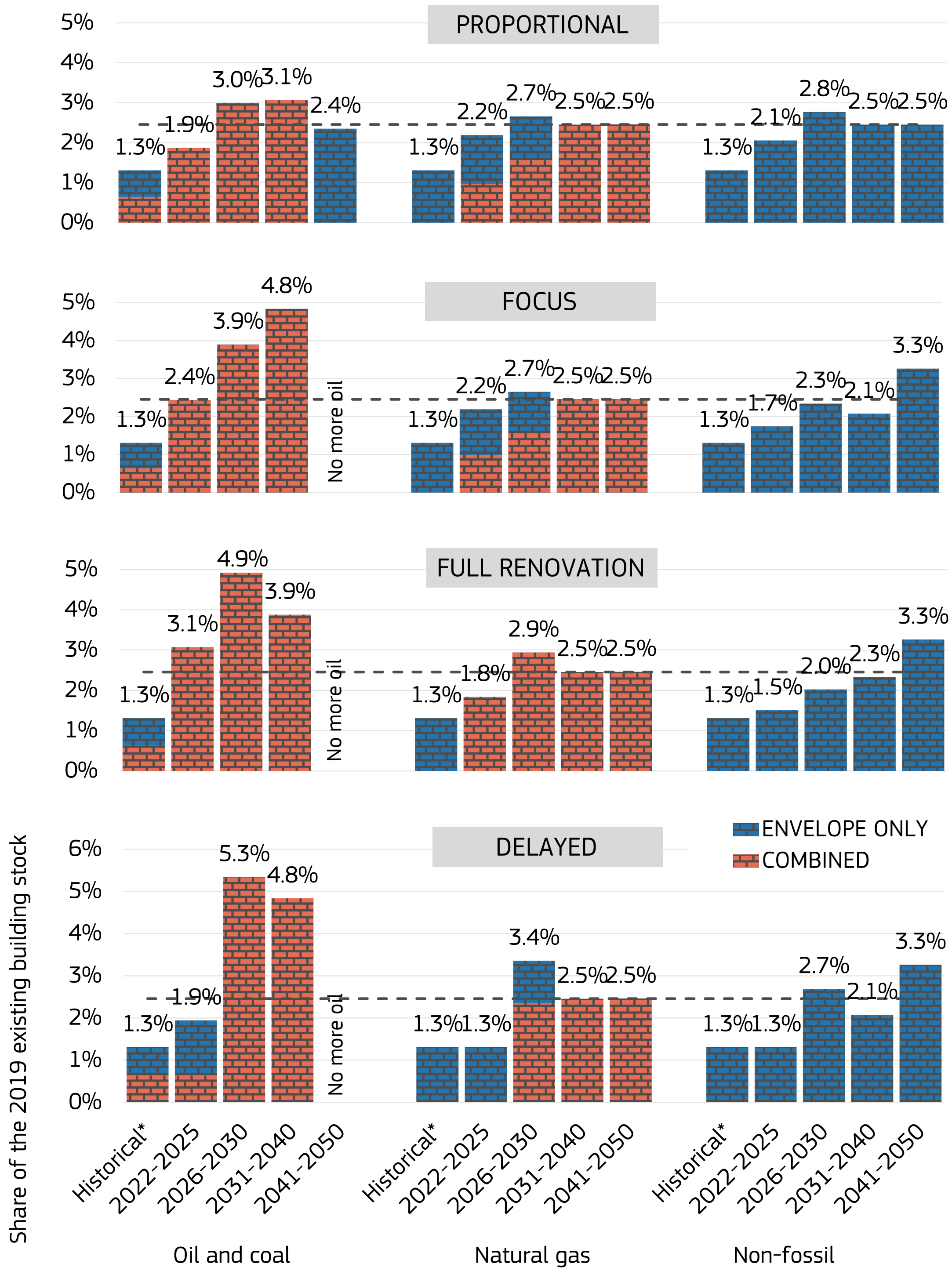
Figure 33 Overview of EU dwellings that undergo an envelope renovation by fuel.



Source: JRC.

Interestingly, our analysis gives a new perspective on ENVELOPE ONLY renovations. The carrying out of envelope renovations without a fuel switch to low-carbon heating need to stop around 2025 for dwellings currently using oil/coal, and soon after 2030 for dwellings using natural gas (**Figure 34**).

Figure 34 Annual envelope renovation rates, split by ENVELOPE ONLY and COMBINED renovations.



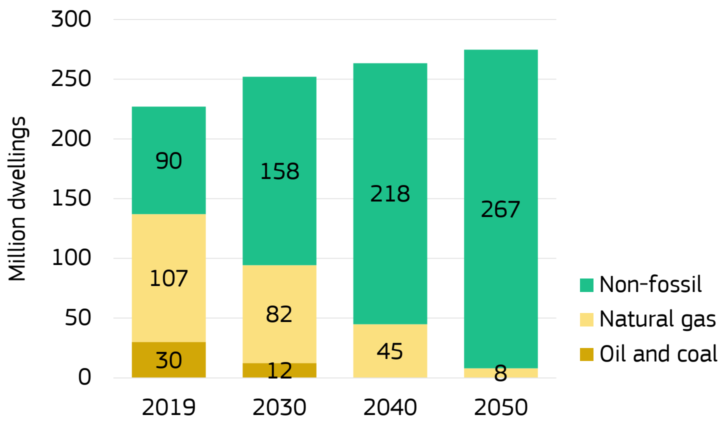
Source: JRC.

7.3 Scaling up heating system renovations

We analyse here the share of buildings that convert away from coal, oil and gas (**Figure 35**). The Renovation Wave strategy mentions a 4% replacement of heating systems, which is around double the targeted level of envelope renovations. This would mean around 9 million dwellings replacing their heating system every year. In our analysis, around 45 million existing dwellings switch their fossil fuel boilers to heat pumps or district heating by 2030. Assuming that new dwellings are mostly heated with non-fossil energy, there are also around 20 million new heating systems by 2030.

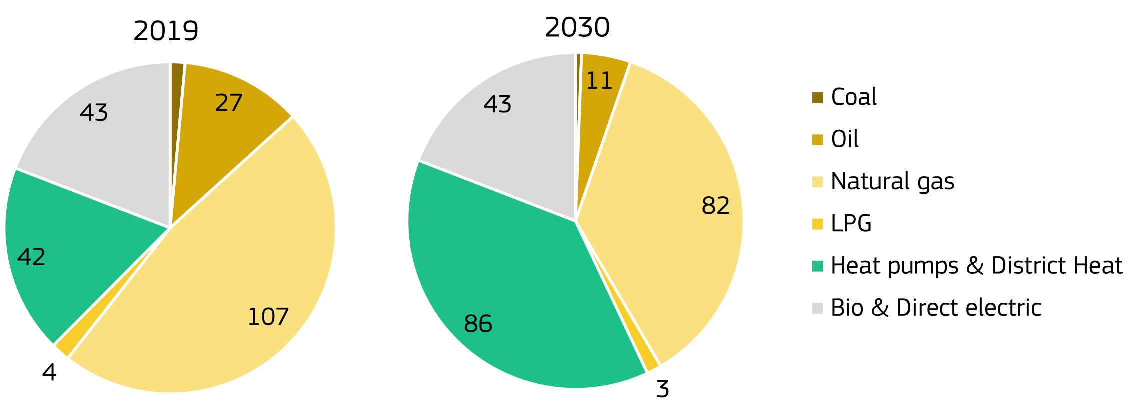
The comparison of scenarios unveiled interesting insights for the period up to 2030 in terms of the uptake of clean and low-carbon energy technologies. By 2030, at least 40 million existing dwellings should switch their fossil fuel boilers to low-carbon heating alternatives. By 2030, we estimate that dwellings on heat pumps and district heating will double compared to today's figures (**Figure 36**) if there is a limited increase in biomass and solar energy. This is an effective average increase of the *dwellings* on heat pumps and district heating of 7% every year. According to (European Commission, 2021i), the *sales* of heat pumps used as the main heating system in EU21 (EHPA countries) reached 1.61 million units in 2020, and have been growing on average 12% annually over the last five years. If this growth continues, an additional 31 million heat pumps will be sold.

Figure 35 Projection of number of dwellings by heating system in the FOCUS scenario



Source: JRC.

Figure 36 Projection of number of dwellings (million dwellings) by heating source in 2030 compared to today



Source: JRC.

Overall insights from our analysis:

- On average, energy scenarios see a 60% reduction in oil and coal use and a 30% reduction in natural gas use by 2030, compared to 2019.
- By 2030, 60% of coal and oil boilers disappear and also one in four natural gas boilers. This will require deep renovations, district heating and electric heat pumps. Heat pumps take heat out of the air or ground much more than they consume electricity.
- A 2.5% renovation rate of the buildings envelope (with an average 67% reduction of energy demand) consists increasingly of renovations that also include a switch away from oil (COMBINED renovation).
- The period 2026-2030 has the highest level of renovations to guarantee that fossil is reduced sufficiently by 2030. In that period, the total renovation rate is around 4%, of which 65% involve renovations switching away from oil. In the period 2030-2040, COMBINED renovations are the highest because after 2040 there are no more dwellings using oil.
- District heating maintains or increases its weight in the sector. In some scenarios, the contribution to heat supply reaches 15%, compared with 7% currently. Due to the electrification of heating and cooling, the growth of heat from heat pumps increases by a factor of 2 to 3.5 and their contribution to the sector's demand is 5% to 7%, compared to about 2% today.

Table 5 Renovation rates residential dwellings as share of 2019 stock, FOCUS scenario

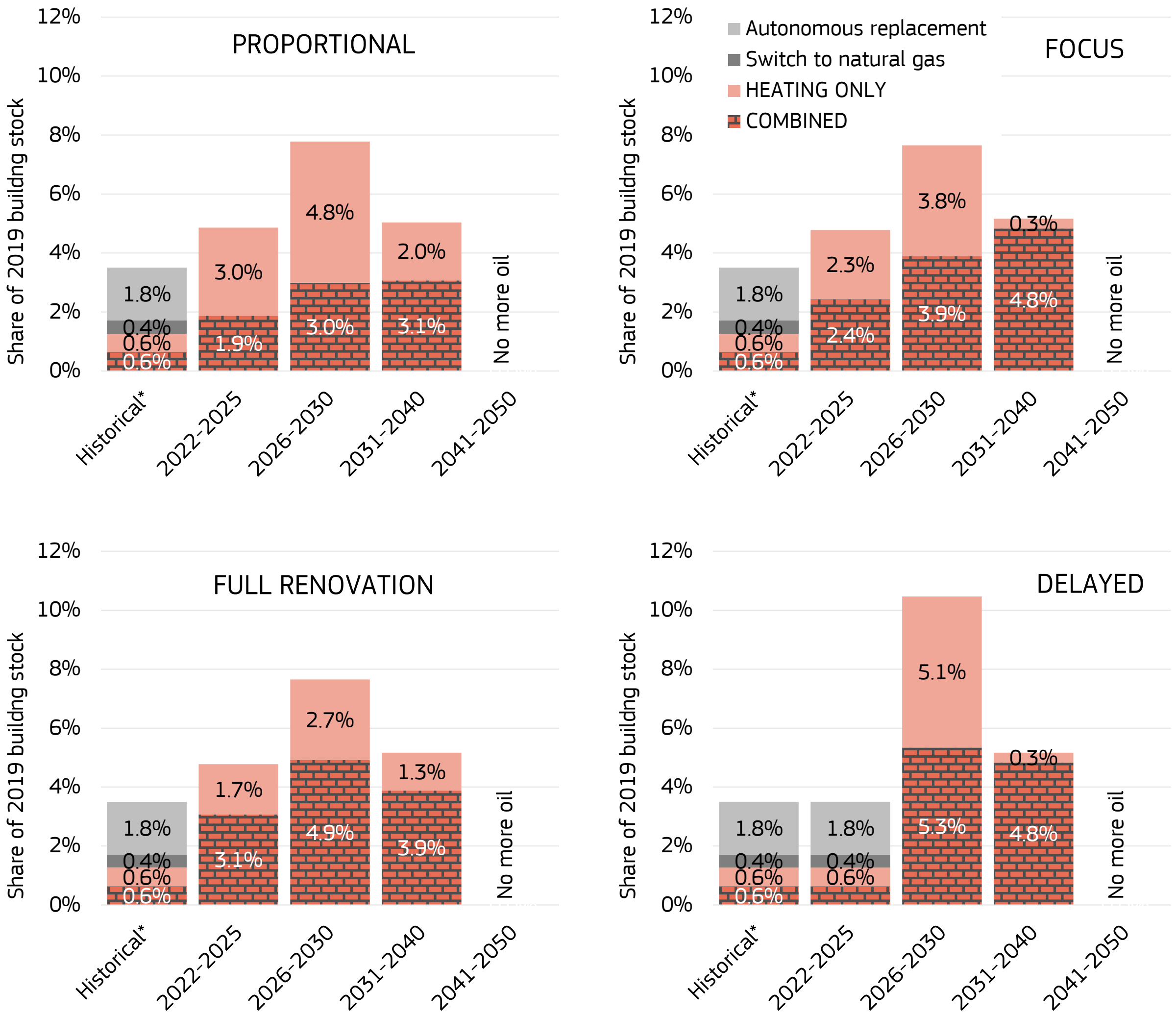
		Historical	2022-2025	2026-2030	2031-2040	2041-2050
Overall	ENVELOPE ONLY	1.2%	1.3%	1.4%	0.8%	1.3%
	COMBINED	0.1%	0.8%	1.3%	1.7%	1.2%
	HEATING ONLY	0.1%	0.8%	1.2%	0.5%	0.5%
Oil & coal	ENVELOPE ONLY	0.7%	0.0%	0.0%	0.0%	0.0%
	COMBINED	0.6%	2.5%	3.9%	4.8%	No more oil
	HEATING ONLY	0.6%	2.3%	3.8%	0.3%	No more oil
Natural gas	ENVELOPE ONLY	1.3%	1.2%	1.1%	0.0%	0.0%
	COMBINED	/	1.0%	1.6%	2.5%	2.5%
	HEATING ONLY	/	1.0%	1.6%	1.0%	1.0%
Non-fossil	ENVELOPE ONLY	1.3%	1.7%	2.3%	2.1%	3.3%

Note: For oil & coal in 2031-2040, 8 years was used instead of 10 years; *Source*: JRC.

Insights for dwellings currently using oil:

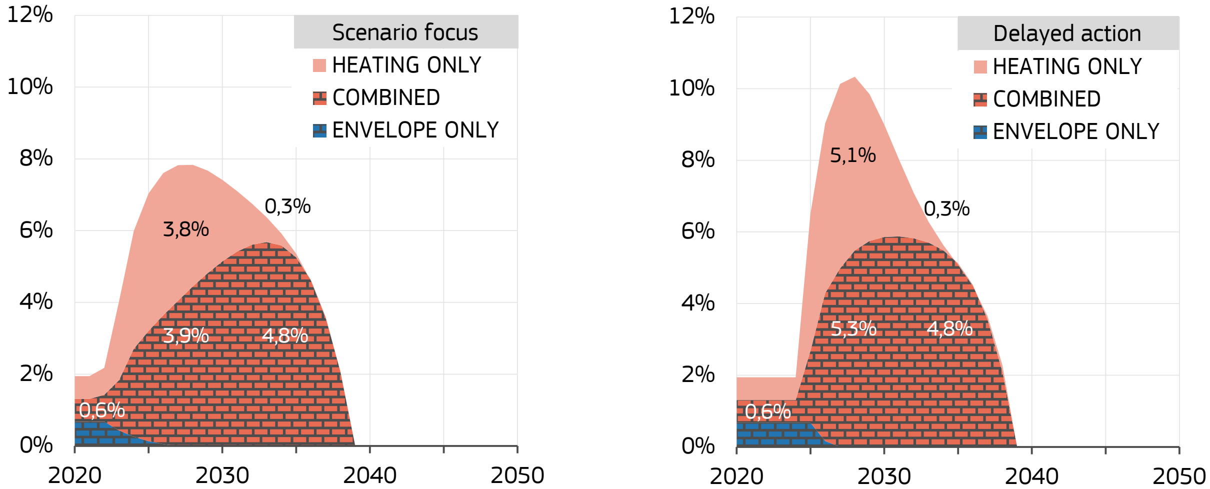
- High renovation rates are required to fully decarbonise before 2040 (FOCUS - OIL). To decarbonise in a period of 15-20 years, an average renovation rate of around 6% is required for renovations that switch to low-carbon heating (HEATING ONLY + COMBINED renovation).
- The phasing out of new oil heating boilers should take place as soon as possible. We recommend renovation should no longer take place without also switching fuel.
- All countries using oil need to increase the replacement rate of residential oil boilers to around 5% until 2025 and to more than 7% in 2026-2030. In the period 2026-2030, this implies that boilers need to switch to low-carbon heating at a rate higher than the default replacement rate, which is typically between 3% and 4%. This rate is double the one from default replacements as observed in the past and that includes like-with-like replacements eg old oil boiler replaced with new oil boiler.
- By 2030, around 55% of the oil boilers in existing residential buildings have to go (15 million dwellings).
- For dwellings currently using oil fuel, hybrid technologies such as hybrid heat pumps may be efficient in the short term, but are not compatible with a phase-out ambition in the mid-term.

Figure 37 Annual heating system replacement rates for dwellings currently using oil, by period.



Note: For oil & coal in 2031-2040, 8 years was used instead of 10 years; *Source*: JRC.

Figure 38 Year-by-year annual renovation rates for dwellings currently using oil.

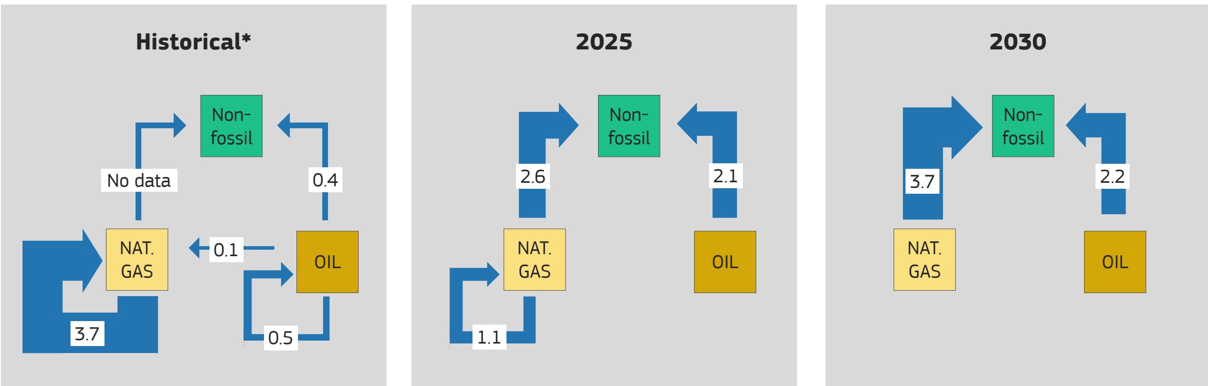


Note: In FOCUS, there are increased renovation efforts in the most carbon intensive dwellings.
In DELAYED, renovations scale up only in 2026, rather than in 2022 (more details in chapter 7.1); Source: JRC.

Insights for dwellings currently using natural gas:

- By 2030, 18% to 23% of the gas boilers in existing residential buildings are eliminated (20 to 26 million dwellings).
- New gas boilers are limited from 2026 (the market size of new gas boilers reduces from 4 million today to 1- 2 million per year in the period 2026-2030), see **Figure 39**. The 2.6 million dwellings per year is 2.4% of the 107 million stock of gas boilers. As of 2026, 70-90% of gas boiler replacements must be low-carbon heating systems. The 3.7 million dwellings per year is 3.5% of the 107 million stock of gas boilers. The historic replacement rate of natural gas boilers is estimated at 3.5% and is based on the age distribution of gas boilers in Germany (bdew, 2019) and on a generic replacement model. In 2019 in Germany, 64% of the gas heating systems were younger than 20 years. In fact, 4.5% of the stock was younger than 5 years, 3.4% between 5 and 10 years and 2.5% is between 10 and 20 years.
- ENVELOPE ONLY renovations for dwellings decrease and the majority of renovations are COMBINED renovations. In the period 2026-2030, the total renovation rate is around 4%, of which 75% involve switching away from natural gas.
- By design, the scenarios PROPORTIONAL and FOCUS are the same for natural gas.
- If action is delayed and historic renovation rates continue until 2025 (**Figure 40**), the heating system renovation rate will have to be very high between 2026 and 2030 (4.8%) to make up for the lost time. This rate could be difficult to achieve for two reasons. First, it is higher than the default replacement rate, which means that simply stopping the installation of new oil or coal heating devices is not enough. Second, a gradual scale-up of the replacement rate starting now will lead to less pressure in the future. If action is delayed, the net replacement rate has to scale up very suddenly from negligible numbers to 4.8%. The strong message from this scenario is that if replacement to low-carbon heating is not addressed as soon as possible, it becomes very difficult to reach the 2030 ambition.
- Hybrid technologies such as hybrid heat pumps can be very cost efficient in reducing the use of natural gas. When using hybrid technologies, the number of dwellings switching away from natural gas needs to be around 25% higher[14]. If only hybrid technologies are used, one in three natural gas boilers should go rather than one in four. The total number of renovations would increase by 6% and the number of ENVELOPE ONLY renovations would be reduced.

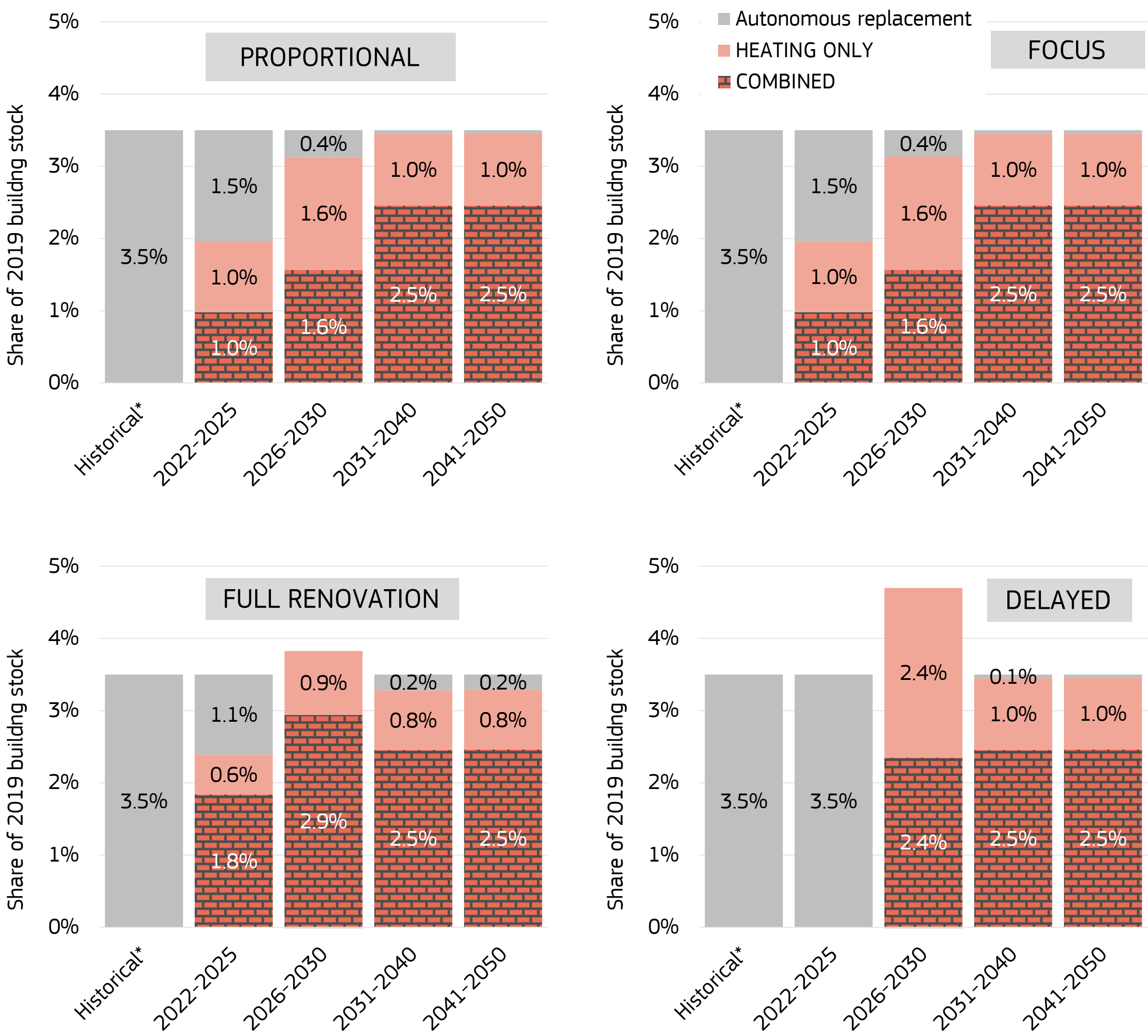
Figure 39 Annual replacement of space heating systems in residential buildings – FOCUS scenario (million dwellings per year)



Note: (*) Historical switching of oil to non-fossil is an EU average while the switch from oil to gas is based on data for Germany.
Note: Based on scenario FOCUS that assumes increased renovation efforts in the most carbon intensive dwellings; Source: JRC

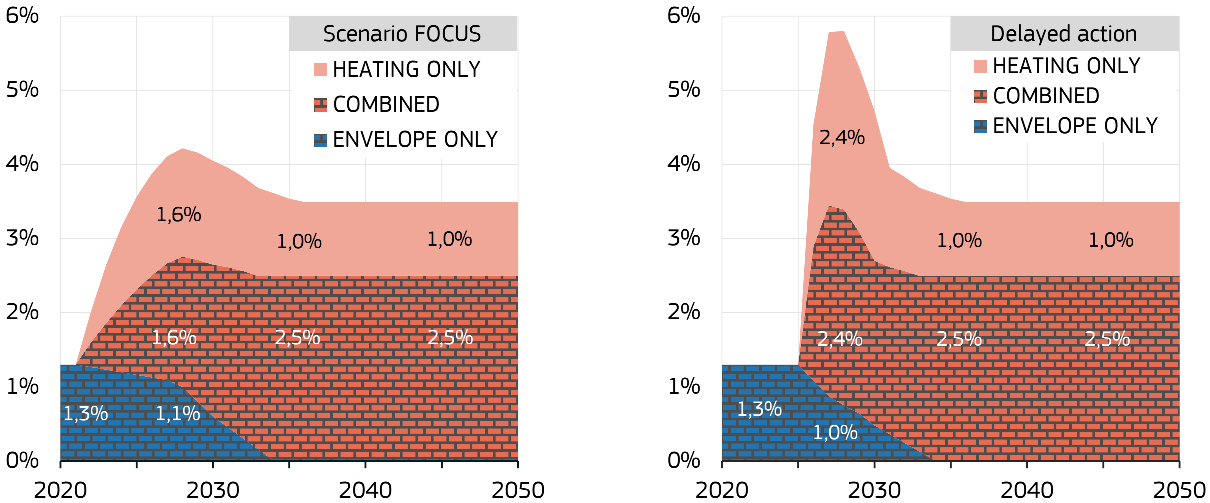
14 Different studies show (Guidehouse, 2021), (Bagarella, Lazzarin, & Noro, 2016) that heat pumps can replace between 30% and 95% of gas demand in a hybrid system. Industrial partners have produced more optimistic results (Aspeslagh & Debaets, 2013). Differences in the thermal efficiency of the building, heating system used and climate are the main factors affecting the share of heat demand coverable by heat pumps. The selection of heat pump size, operation mode and differences in energy price regimes also affect the share of heat pump and gas boiler.

Figure 40 Annual heating replacement rates for dwellings currently using natural gas, by period.



Source: JRC.

Figure 41 Year-by-year annual renovation rates for dwellings currently using natural gas.



Note: In FOCUS, there are increased renovation efforts in the most carbon intensive dwellings.
In DELAYED, renovations scale up only in 2026, rather than in 2022 (more details in chapter 7.1); *Source*: JRC.

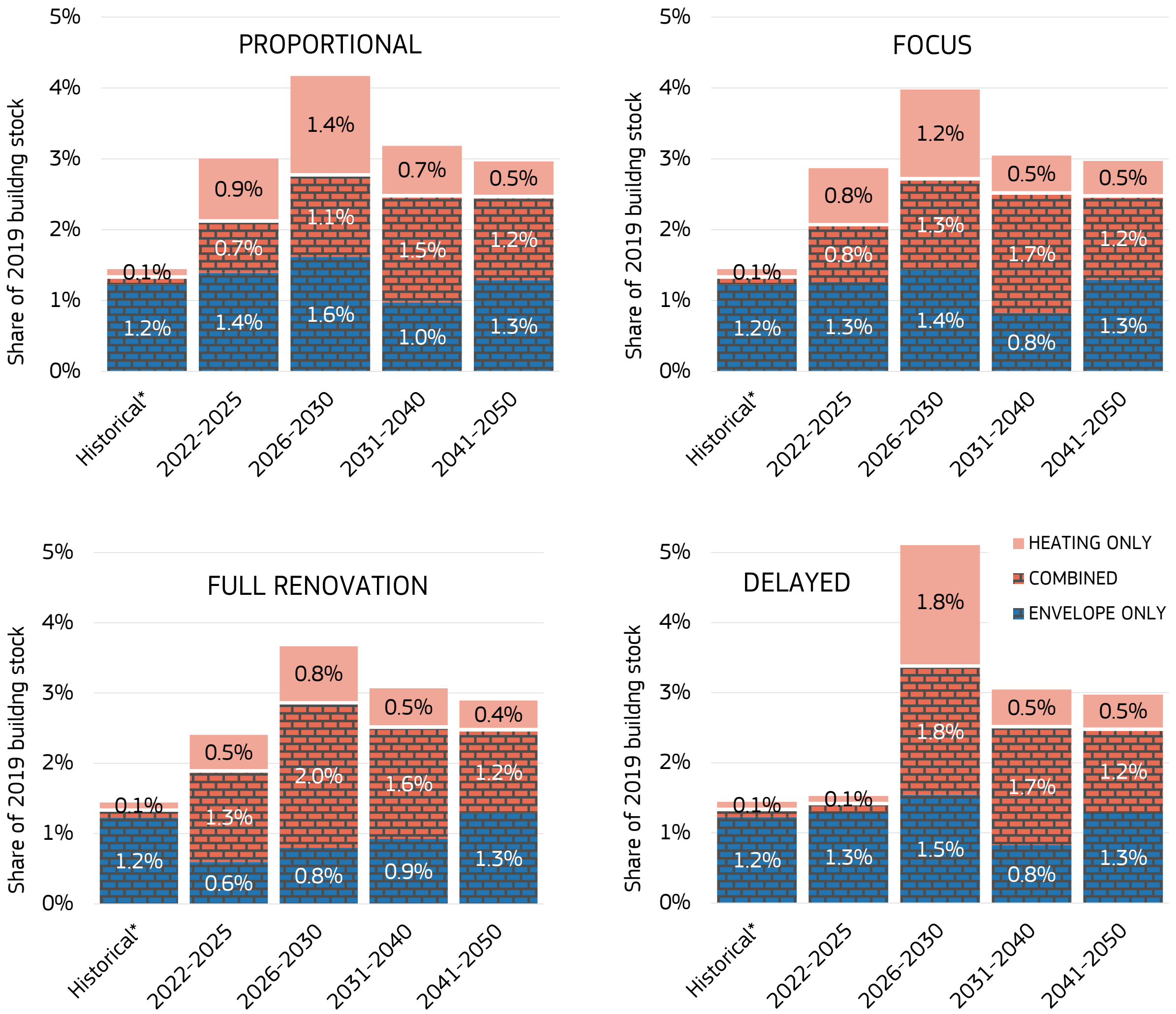
7.4 Overview of energy and heating system renovations

In this section, we look at all types of renovation and the balance between energy and heating system renovations. As 2030 is fast approaching, the speed of different transformations is crucial. This analysis concludes that a strong increase in envelope renovations is not sufficient (15% reduction of heat demand in the next 10 years) and for that reason, the supply side plays an important role.

The balance between lowering energy demand and decarbonising the heat supply is also discussed in (RAP, 2021). The cost-efficient levels of energy (envelope) and heating system (fuel switch) renovations for reducing carbon emissions depend on the fuel and electricity prices and the current energy performance of the building. This cost-efficient level is out of the scope of this report, however we summarise insights related to this balance:

- According to most energy scenarios, deep renovation rates should increase at least tenfold in order to reach climate neutrality.
- From our analysis, we conclude that ENVELOPE ONLY renovations decrease strongly for dwellings fuelled by oil and gas because not enough fossil fuel is reduced at the level of the total building stock. The reduction is too low despite an annual envelope renovation rate of 2.5% and despite reaching an average energy reduction of 65% at the dwelling level. Therefore, envelope renovations in dwellings currently using fossil fuel will need to reorient towards COMBINED renovations that combine efficiency improvements in the building shell with a fuel switch.
- Low energy renovations (reducing energy demand by 20%) that also decarbonise the heat supply are part of the category COMBINED renovations. In our analysis, most of the energy renovations consist of medium or deep renovations (see **Table 4**). Only 6% of energy renovations (ENVELOPE ONLY or COMBINED) or 4% of total renovations are low energy renovations. This does not mean renovations with limited energy renovation are not important. In fact, renovations with no or limited energy renovation are part of the category HEATING ONLY renovations when they switch away from fossil fuels. In our analysis, this category plays an important role, making up 30% of total renovations.

Figure 42 Overview of all renovations in the total dwelling stock by period.

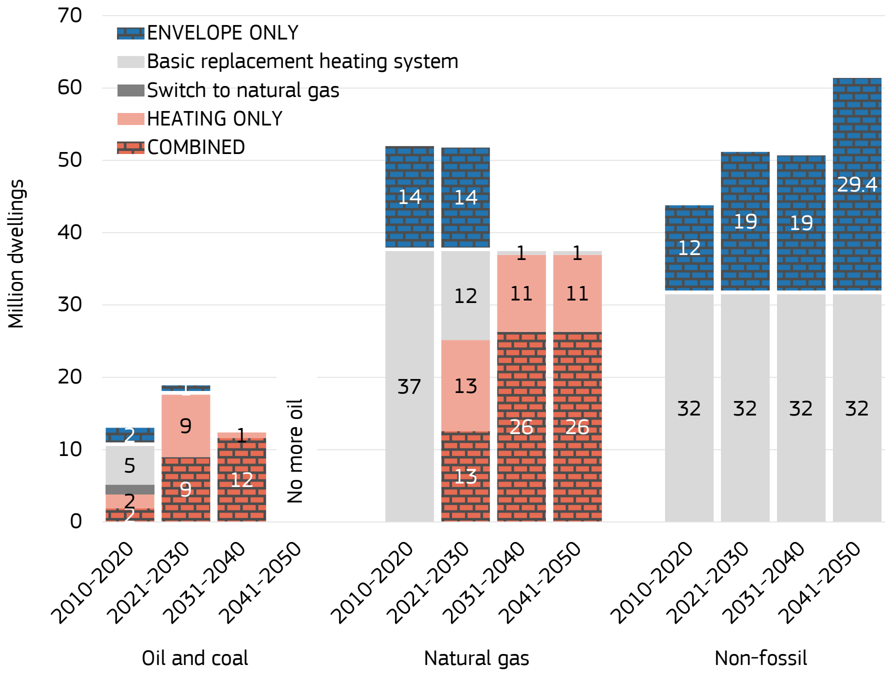


Source: JRC.

We provide here new insights on renovations which include fuel switches. Our analysis shows that in the period 2022-2030, low-carbon heating is introduced into more than 15 million dwellings (55%) currently using oil or coal and into around 25 million dwellings (one in four) currently using natural gas (FOCUS scenario, **Figure 43**).

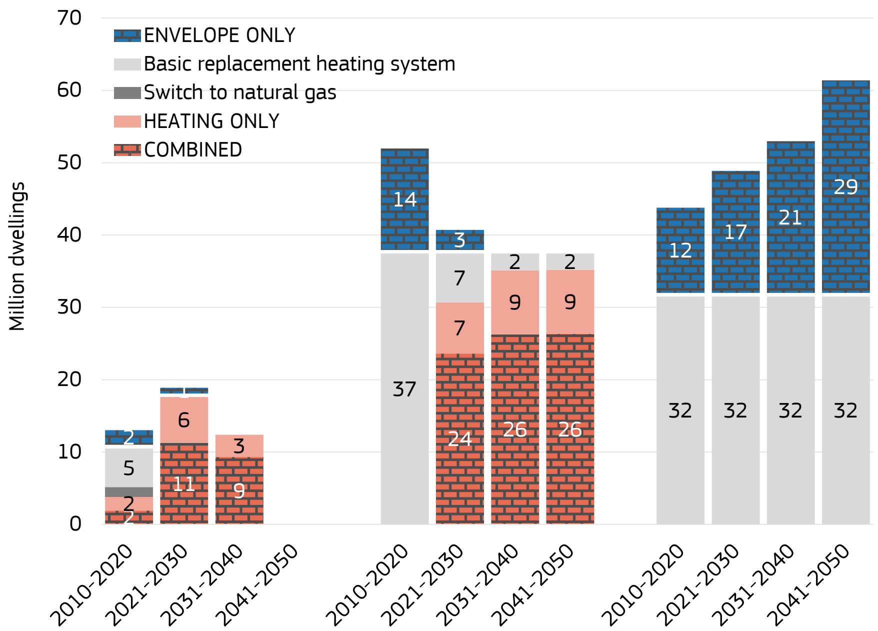
In a scenario with a higher rate for COMBINED renovations (FULL RENOVATION scenario), this could reach as high as 30 million dwellings (or 28%) currently using natural gas (**Figure 44**). The advantage of this scenario is that the total number of renovations is smaller because there are more combined renovations than in the more phased approach of the FOCUS scenario. This is possibly more cost-efficient but also more demanding in the early stages up to 2030.

Figure 43 Overview of renovations by heat source and by period, FOCUS scenario.



Source: JRC.

Figure 44 Overview of renovations by heat source and by period, FULL RENOVATION scenario.



Source: JRC.

8 Investments estimate based on renovation scenarios

According to the EU Renovation Wave[15], building renovation is one of the sectors facing the largest investment gap in the EU. To achieve the proposed 55% climate target by 2030, around EUR 275 billion is needed in building renovation investment every year in the residential and services sectors. Investments in the buildings sector are expected to double in the next decade. All analysed scenarios foresee a rapid increase in both envelope renovations and heating system renovations. In the EC FF55 REG scenario, the bulk of the investment is expected to reach EUR 194 billion annually in the residential sector in 2021-2030. This is 54% higher than in the reference scenario and more than double the historic investments in 2011-2020 (European Commission, 2021h).

These numbers include new construction, hot water preparation, cooling and cooking, while our analysis is limited to space HEATING ONLY. The investment estimates are directly linked to the three types of renovation of existing buildings: ENVELOPE ONLY, HEATING ONLY and COMBINED renovation.

The following data sources and assumptions are used for the investment estimate:

- The investment estimates are based on the renovation scenario, FOCUS, discussed in this report. Because each renovation scenario starts from the same reduction of fossil fuels and has the same total number of envelope renovations for each decade, the total investments are reliably comparable among renovation scenarios.
- The cost of building envelope renovation at different depths is based on literature review (Tractebel, 2018), (Ipsos Belgium/Navigant, 2019), (Bertoldi, Economidou, Palermo, Boza-Kiss, & Todeschi, 2020), (European Commission, 2021d) and on the cost of projects already implemented (AMiestas, 2021).
- The cost of replacing heating equipment and switching to low-carbon heating systems is based on current prices. For the basic heating system replacement we assume the same type of heating system (gas boilers replaced by gas boilers, etc.).
- For the switch to low-carbon heating systems we use low temperature, air-liquid heat pumps as a proxy. The energy scenarios analysed do not point to a massive switch to district heating or direct use of biofuels, leaving heat pumps as the solution with the largest increase. In southern EU, air-air heat pumps could be a more optimal solution (lower cost and the potential to meet cooling demand with the same device) but air-liquid-based heat pumps are likely to dominate in the rest of the EU.

Based on the above assumptions, the required investments for building renovation amount to around EUR 159 billion per year in the period 2022-2030. For the period 2030-2050, this is around EUR 171 billion a year, see **Figure 45** (left). That is equivalent to around 1% of the EU's GDP in 2019, and around 21% of the construction sector's GDP today (Eurostat, 2021).

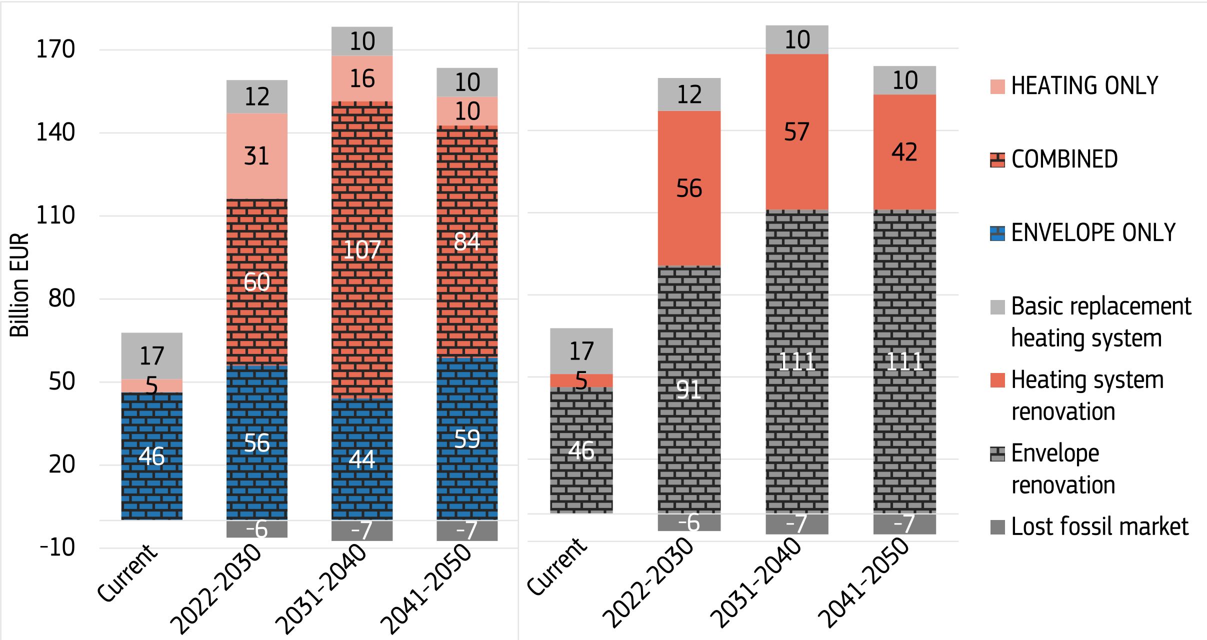
The largest part of the renovation budget (around EUR 100 billion a year) will go to envelope renovations **Figure 45** (right). Another EUR 50 billion will go to switching heating systems from gas/oil/coal to low-carbon alternatives, driving growth in these sectors (HM Government, 2021). Estimations of these investment costs for building renovations suffer from a high level of uncertainty in areas such as regional differences (different meteorological conditions, building codes, labour and material costs influence the cost of energy renovation) and specific situations in individual dwellings. Nevertheless, our results are very comparable to the EC FF55 REG scenario that includes around EUR 80 billion for thermal integrity improvements of existing dwellings and at least EUR 50 billion for the installation and upgrade of space heating equipment. At the same time, the existing market of fossil fuel boilers will diminish: to meet the EU Fit for 55 goals, no new oil or coal boilers should be installed (including the replacement of existing boilers at the end of their economic lifetime). The

[15] Renovation Wave COM(2020) 662

gas boiler market may shrink by 70% by 2025, reducing the market size of new gas boilers from over 4 billion today (ehi, 2020) to below 1.5 billion. From 2026, the new gas boilers market will be marginal.

We conclude that, despite a noticeable reduction in fossil-based boilers and the installation market (loss of EUR 6-7 billion a year), the envelope renovation market may double (driven by the increasing renovation rate and depth) and the sales and installation of heating systems triple (driven by higher equipment costs and the extra effort needed to retrofit existing systems, for example going from high- to low-temperature central heating systems).

Figure 45 Yearly cost of renovation in FOCUS scenario, right – splitting COMBINED renovation into components (markets)



Source: JRC.

9 Policymaking challenges for the transition to 2030

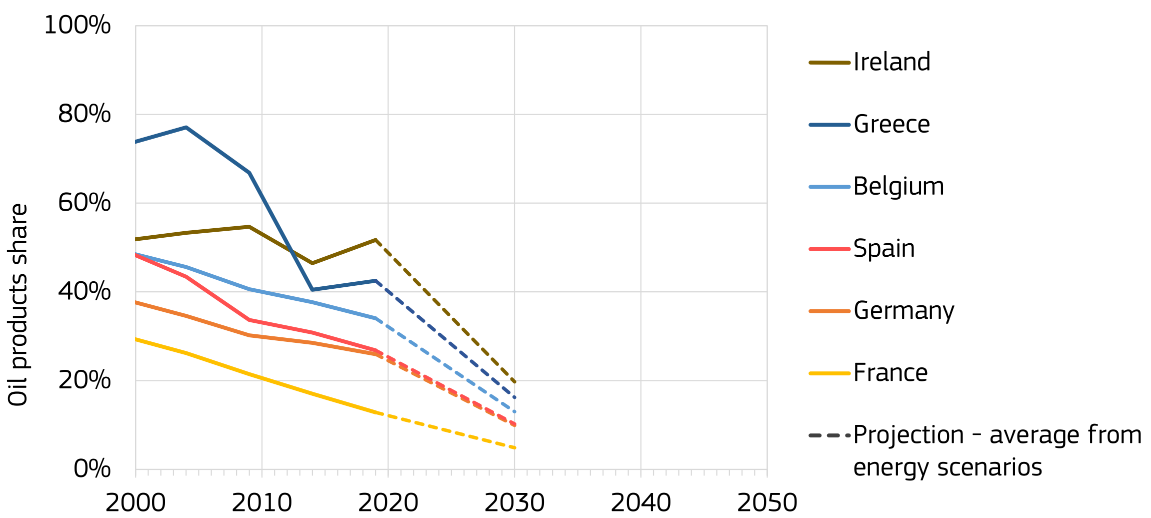
Energy scenario studies often provide technical indicators but do not always translate their findings on reducing fossil fuel use into specific policies. The policy challenges are enormous, but can be hard to discern in technical studies where critical assumptions are not made clear or where the right indicators are not selected. Heating systems in buildings are on the list of indicators that need more focus according to (IRENA and JRC, 2021). This chapter starts with the gap between current trends and what energy scenarios project. Current EU and national policies for the decarbonisation of buildings are summarised in the next two sections. The last two sections shed light on the challenges facing policymakers in terms of increasing both envelope and heating system renovations. The historical relation between policies and energy renovations is out of the scope of this report.

9.1 The gap between current trends and what energy scenarios project

In this section we contrast historical data on fossil fuel use with energy scenario projections for a selected number of countries. We compare historical efforts with the changes required to reach what energy scenarios depict. For residential buildings, we look at the historical and projected share of oil products in final energy use for heating. Oil and LPG use is high in the six selected countries and is, according to the scenarios, to be phased out before 2040. For the residential sector, almost all countries need to increase the replacement rate for oil boilers as shown in **Figure 46**.

Although not shown in the figure, the current trend in the services sector is more in line with projections. We conclude that enough oil boilers are already being replaced in the services sector, although differences exist between countries.

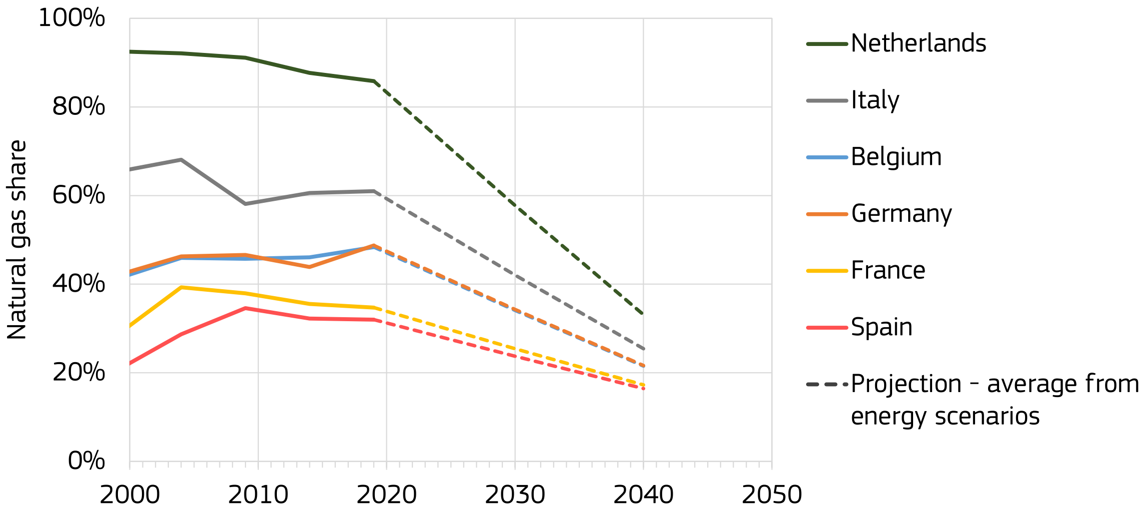
Figure 46 Historical and projected share of oil products (OIL + LPG) in final energy use for heating residential buildings.



Source: JRC – based on Eurostat and the selected energy scenarios

For the share of natural gas in final energy use for heating, the gap between the trend and the projections is larger. For some countries, the share of gas has to decrease in the next nine years by around 25% (**Figure 47**).

Figure 47 Historical and projected share of natural gas in final energy use for heating residential buildings.



Source: JRC – based on Eurostat and the selected energy scenarios

9.2 EU policies

The new climate target of the European Union is to reduce GHG emissions by 55% by 2030, compared to 1990 levels. Moreover, with the new Climate Law, the EU has to reach climate neutrality by 2050. These targets cannot be achieved without reducing energy consumption in the European buildings sector. Decarbonisation of the buildings sector requires actions in the following main areas: energy efficiency (building renovation, efficiency of heating and cooling supply), phase-out of fossil fuel-based boilers, increasing the share of renewable energy systems (in both individual heating and cooling, and central heating and cooling supply). To address all these areas of action, there is a need for target-oriented policies and measures in several fields.

The European Commission released its European Green Deal in November 2019, its proposal for a European Climate Law in March 2020, its 2030 Climate Target Plan in September 2020, its Renovation Wave initiative for the buildings sector in October 2020 and the first tranche of its Fit for 55 package containing the proposals required for delivering the European Green Deal in July 2021[16]. One of the actions proposed in July was the introduction of carbon pricing for buildings by regulating fuel suppliers from 2026. The following instruments and their revision[17] are also relevant: the EU Strategy for heating and cooling[18], the Energy Performance Building Directive[19] (EPBD), the Energy Efficiency Directive[20] (EED), the Renewable Energy Directive[21] (RED II) and the Ecodesign and Energy Labelling regulations that set consistent EU-wide sustainability requirements for space and water heating devices. With the Renovation Wave for Europe, the European Commission has set an objective to at least double the annual energy renovation rate of residential and non-residential buildings by 2030 and to foster deep energy renovations.

The package for delivering the EU Green Deal (European Commission, 2021a) mentions:

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[16] European Green Deal COM(2019) 640; European Climate Law COM(2020) 80 final; 2030 Climate Target Plan COM(2020) 562; Renovation Wave COM(2020) 662 and the proposals required for Delivering the European Green Deal (European Commission, 2021a).

[17] Revision in the frame of the Fit for 55 package

[18] EU Strategy on Heating and Cooling (COM(2016) 51 final)

[19] Energy Performance Building Directive (Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings)

[20] Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency

[21] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources

— The new Social Climate Fund will support EU citizens most affected or at risk of energy or mobility poverty. It will help mitigate the costs for those most exposed to changes, to ensure that the transition is fair and leaves no one behind. It will provide EUR 72.2 billion over seven years in funding for renovation of buildings, access to zero and low emission mobility, and income support.

— In addition to homes, public buildings must also be renovated to use more renewable energy, and to be more energy efficient. The Commission proposes to:

  - require Member States to renovate at least 3% of the total floor area of all public buildings annually;
  - set a benchmark of 49% of renewables in buildings by 2030;
  - require Member States to increase the use of renewable energy in heating and cooling by +1.1 percentage points each year, until 2030.

Areas of intervention and lead actions include the following.

— Strengthening information to undertake renovation. Revision of the EPBD (including a proposal for Energy Performance Certificates alongside a phased introduction of mandatory minimum energy performance standards for existing buildings).

— Promoting the decarbonisation of heating and cooling (through the 2021 revisions of the Renewable Energy and Energy Efficiency Directives and the EU ETS, the application and further development of eco-design and labelling measures, as well as support to district approaches).

— Under RED II and its revision, the Member States must endeavour to increase their RES shares, including for heating and cooling.

More information on EU policies is provided by a recent study (Öko-Institut e.V., 2021). The following subsections provide a short overview of the most important elements of EU policy in relation to the decarbonisation of buildings.

9.2.1 Energy performance of buildings (EPBD) and its revision

A revision of the EPBD was one of the initiatives of the 2021 Fit for 55 package. In this revision, the standards for new buildings may be upgraded from nearly-zero energy to zero-emission buildings. Such a definition could rule out the installation of fossil fuel-based heating appliances in new buildings.

The previous revision of the EPBD was part of the Clean energy for all Europeans package. It requires Member States to set minimum energy performance requirements expressed in primary energy use for buildings or building units to achieve cost-optimal levels. Member States can, however, set more specific requirements to make sure that the overarching goals are met. The EPBD requires Member States to set minimum requirements at the level of the whole building in terms of primary energy. Additionally, it requires Member States to set minimum requirements at the level of individual building elements (e.g. window and envelope) and technical building systems (heating efficiency, heat recovery, specific fan power, and thickness of insulation for pipework).

Apart from how they affect the energy needs of the whole building system, space heating systems are not the concern of the EPBD because they are a standalone component. Still, the energy performance is calculated in primary energy and therefore the type of energy used matters for its calculation. Improvements to energy performance through building renovation include both the building shell and the heating and cooling appliances, and other technical building systems.

The existing EPBD requires Member States to establish long-term building decarbonisation strategies that include national measures and policies for the buildings sector and information on the types of energy used in buildings.

9.2.2 Energy efficiency (EED) and its revision

In July 2021, The European Commission published a proposal to recast the Energy Efficiency Directive (EED), seeking to introduce higher targets for reducing primary (39%) and final (36%) energy consumption by 2030.

These new targets, up from the current target of 32.5% for both primary and final consumption, would be binding at EU level, in line with the Climate Target Plan.

Under the EED, each Member State must set up an energy obligation scheme or alternative policy measures to achieve end-use savings. Member States must carry out a comprehensive assessment of the potential for energy efficiency in heating and cooling. Based on this analysis, Member States have to define strategies, policies and measures to meet the targets.

What follows is a selection of new elements from the revision of the Energy Efficiency Directive, as proposed in July 2021 (European Commission, 2021a).

- A revised definition of efficient district heating and cooling would directly promote the deployment of renewable energy in district heating and cooling. An efficient district heating and cooling system is a system which meets the following criteria:
    a) until 31 December 2025, a system using at least 50% renewable energy, 50% waste heat, 75% cogenerated heat or 50% of a combination of such energy and heat;
    b) from 1 January 2026, a system using at least 50% renewable energy, 50% waste heat, 80% high-efficiency cogenerated heat or at least a combination of such thermal energy going into the network where the share of renewable energy is at least 5% and the total share of renewable energy, waste heat or high-efficiency cogenerated heat is at least 50%;
    c) from 1 January 2035, a system using at least 50% renewable energy and waste heat, where the share of renewable energy is at least 20%;
    d) from 1 January 2045, a system using at least 75% renewable energy and waste heat, where the share of renewable energy is at least 40%;
    e) from 1 January 2050, a system using only renewable energy and waste heat, where the share of renewable energy is at least 60%.
- While the existing EPBD sets minimum energy performance requirements for all buildings that undergo major renovation, Article 5 of the EED sets a binding renovation target for public buildings and imposes related obligations. It also stresses that governments shall undertake an exemplary role in the energy retrofit of their countries' building stock. Article 5 of the EED stipulates that all Member States shall ensure that 3% of the total floor area of heated and/or cooled buildings owned and occupied by its central government is renovated each year to meet at least the minimum energy performance requirements.
- Each Member State must set up the energy obligation scheme or alternative policy measures to achieve end-use savings. Under this article, Member States can support the installation of fossil-gas boilers based on their efficiency compared to the replaced system (RAP, 2021).
- The EED requires each Member State to carry out and submit to the Commission a comprehensive assessment including:
    - heating and cooling demand in terms of assessed useful energy and quantified final energy consumption;
    - identification (or estimation) of current heating and cooling supply;
    - a map covering both heating and cooling demand and supply;
    - a forecast of trends in the demand for heating and cooling to maintain an oversight of the next 30 years.

9.2.3 Promotion of the use of energy from renewable sources (REDII) and its revision

The revision of RED II (RED III) increases renewables ambition in the Heating and Cooling sector. This is a central plank of the delivery of the overall RES ambition. The list of measures has been expanded and includes district heating and buildings. The proposal of July 2021 outlines the following new targets at national level aimed at stimulating change for:

- Buildings: a new benchmark of 49% renewables use by 2030 (article 15a);
- heating and cooling: the existing indicative 1.1 percentage point annual increase becomes binding on Member States, with specific indicative national top-ups;

— district heating and cooling: an indicative 2.1 percentage point annual increase in the use of renewables and waste heat and cold (an increase from the current 1.0 percentage point increase).

9.2.4 Eco-design and labelling

Another way to promote the decarbonisation of heating and cooling is through Ecodesign or Energy Labelling standards for new heating systems. The performance of standalone components does not fall under the EPBD, but does fall under the scope of product-specific regulations implementing the Ecodesign Directive. The Ecodesign Directive makes sure that efficient products are placed on the market, facilitating the delivery of EPBD goals.

The requirements for space heaters are currently under review[22] and entry into application will probably not be until 2024. EU harmonisation can prevent fragmentation and a variety of national requirements that may lead to reduced competition, insufficient economies of scale or negligible competition in cross-border services for installation.

According to (RAP 2021), these should align with climate neutrality and support the phase-out of fossil-fuel boilers. According to (Öko-Institut and Agora Energiewende, 2020), standards could be further tightened to rule out specific types of heating system from being sold to consumers on the domestic market and to phase out the most inefficient fossil-fuel heating systems. In principle, appliance standards could also be used to implement an EU-wide ban of fossil fuel-based heating systems through tighter requirements in line with the EU goal of climate neutrality.

9.2.5 Emissions Trading System Directive (ETS)

The EU Emissions Trading System (ETS) might become relevant for the buildings sector due to its proposed extension to new sectors of the economy (such as buildings and road transport) in its revision (European Commission, 2021e). The impact assessment accompanying the proposed update of the ETS concludes that this has both advantages and disadvantages. Since it would affect individual spending on heating fuels in the short or medium term, it could potentially create challenges in terms of the acceptability of the measure; other consequences may include distributional effects and impacts on vulnerable citizens. However, it can also be used to raise revenues for the public sector, providing resources for climate action or for addressing social and distributional concerns (European Commission, 2020).

According to a study by BPIE (BPIE, 2021b), the possible impact of a carbon price on energy-saving measures or a fuel switch depends, among other factors, on the size of the price increase. Due to a rather low price elasticity in the heating sector, the change of heating fuels will not be significantly impacted in the short to mid-term. Moreover, low-income groups, who are more likely to live in rental housing, do not have the financial means or the ability to invest in energy efficiency measures or a fuel switch. Nevertheless, there are positive examples of using CO_2 pricing for fossil fuels in Europe. After its introduction in Sweden in the early 1990s, the CO_2 tax, among other factors, made an impact on the phase-out of fossil fuels and contributed to a significant decrease of CO_2 emissions from buildings. According to (Agora Energiewende, 2021), the CO_2 tax in Sweden was effective because it coincided with all-inclusive rents. This means that the landlord generally pays the heating and hot water costs. CO_2 pricing might be an effective instrument in the buildings sector, if it is combined with other instruments such as financial support for renewable heating systems. Supporting instruments should be designed to address barriers such as the split-incentive dilemma.

[22] First working documents discussed with stakeholders in September 2021: https://ec.europa.eu/transparency/expert-groups-register/screen/meetings/consult?lang=en&meetingId=28735&fromExpertGroups=true

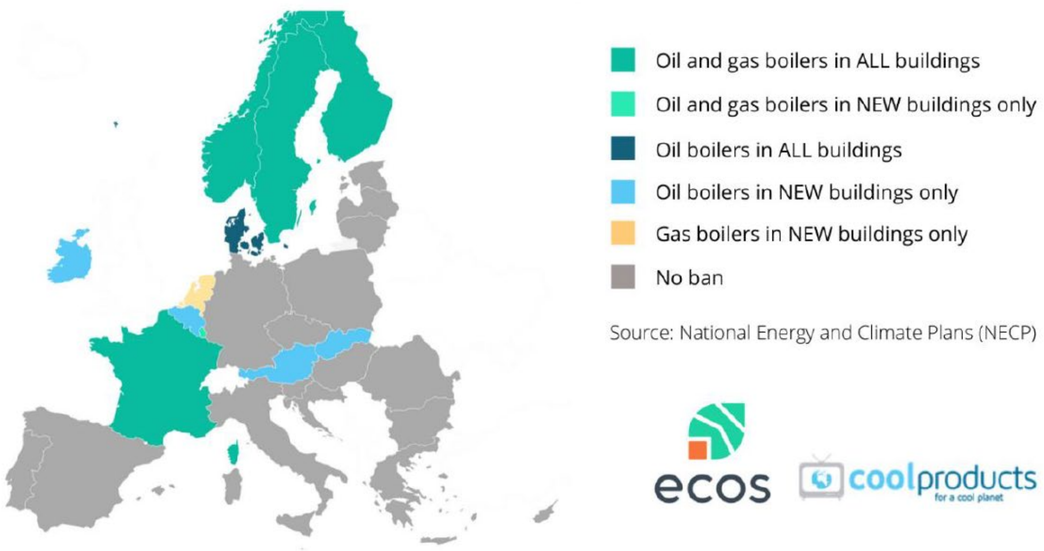
9.3 National policies

EU Member States have very different heating and cooling markets. Some already have a high share of renewable energy sources in buildings, for example in 2019 in Sweden, 34% RES were used directly, and taking into account district heating, it reaches 66%. In Lithuania these numbers are slightly lower: 30% and 47% (Eurostat, 2021). Other countries are still heavily dependent on the direct use of fossil fuels, for example the Netherlands (87%) and Luxembourg (69%). In some countries, a significant share is supplied by district heat (Sweden, Lithuania, Latvia), whereas in other countries, the heat is mainly supplied by individual heating systems (Netherlands, Spain). Given such fundamental differences, it is important that national policies are designed to address the challenges and barriers specific to Member States. Some examples of the policymaking context are offered in Annex 3 and below, and more information on national policies is provided in the studies (ECOS - Environmental Coalition on Standards, 2021) and (Öko-Institut e.V., 2021).

National Energy and Climate Plans (NECPs)

Under the regulation on the governance of the energy union and climate action, Member States submitted their final National Energy and Climate Plans (NECPs) in 2019. These include strategies and measures for energy efficiency, buildings and the heating and cooling sector. NECPs are important documents linking the current situation and national targets to policies and measures. The next round of NECPs should be updated following the objectives of the Fit for 55 package. The briefing (ECOS - Environmental Coalition on Standards, 2021) built a map for the year 2024 (**Figure 48**), providing an overview of the ambition of each country when it comes to phasing out fossil fuels. It is partly based on the NECPs from each country.

Figure 48 End of fossil-fuel heating in the EU by 2024, by type of boiler



Source: (ECOS - Environmental Coalition on Standards, 2021)

Regulatory policies for a fuel switch in heating

Some EU countries have already implemented policies agreeing concrete objectives for various fossil fuels and sectors. For example, Belgium has set an objective to phase out back-up coal in the residential sector by 2030. Germany will eliminate the majority of district heating generation from coal-fired co-generation plants by 2030. Finland will phase out the use of coal in energy production by 2029.

Phasing out fossil fuels for heating can be achieved in different ways. One option is to prohibit the installation of fossil fuel boilers in new construction. This approach was adopted in Austria to phase out oil boilers. In the Netherlands, new houses cannot connect to the gas network since 2020, and 1.5 million homes are expected to have switched from gas by 2030. Another approach is to make use of the end of the economic lifetime of heating systems. For example, if a boiler is older than X years, it has to be replaced by a renewable system. To soften this requirement, it could be accompanied by a subsidy for the new heating system.

Other national policies

- It is quite common for countries to set requirements at the level of generator efficiency (e.g. boiler efficiency). Also, the EPBD allows Member States to set additional requirements in terms of CO_2 (e.g. kg CO_2/m2 year). Ireland has taken this approach.
- Concrete objectives to increase the share of renewable energy: in Estonia and Lithuania, targets have been set for the renewable energy share in district heating by 2030 (80% in Estonia and 90% in Lithuania).
- CO_2 taxes on energy carriers: Sweden and Germany have introduced CO_2 taxes on heating (see Annex 3).
- Other national policies may include financial support for renewable heating systems, long-term decarbonisation targets for the district heating network or the removal of subsidies which allow or even promote fossil fuel-based systems.
- Sector integration can make heat pumps interact with the grid by using wholesale energy prices, tariffs and carbon emission intensities (RAP, 2021).

9.4 Policymaking challenges for increasing envelope renovations

Several scenarios have shown that there is a need for an annual renovation rate of between 2% and 4% to reach the long-term decarbonisation target. The report (BPIE, 2021c) claims that the annual deep energy renovation rate must reach 3% as soon as possible and no later than 2030. According to the ECF Demand scenario, not only the rate of renovation should be increased, but also its quality (i.e. deep renovation that reduces energy consumption by at least 60%).

The current annual renovation rate of existing building stock varies from 0.2% to 12%[23] (European Commission, 2019). While 0.2-0.3% undergoes deep renovation (achieving approximately 60% savings), 12% undergoes some level of renovation (with half achieving less than 3% savings). Increasing the renovation rate and managing a shift to higher quality renovations are two important objectives in the coming decades. This is, however, a big challenge for policymakers, due to many barriers which have slowed down renovation activities across Europe in the past.

The EU Strategy on Heating and Cooling has identified several barriers to energy renovation, depending on various forms of building ownership (European Commission, 2016b). Private owners of residential buildings are often unaware of the benefits of thermal renovation; they also lack advice on the technical possibilities and suffer financial constraints. Split incentives, tenancy rules and financing are the main barriers for privately owned rented buildings.

The EPBD revision that is part of the Fit for 55 package provides a list of barriers including financial, behavioural/consumer, information, administrative, technical and organisational/building complexity. To overcome some of those barriers, the EPBD revision provides a set of actions such as Minimum Energy Performance Standards (MEPS), fiscal or tax incentives and consideration of wider benefits.

Among all existing barriers, financial constraints are identified as one of the major barriers to building renovation (European Commission, 2019), (CE Delft, 2020), (Zangheri, et al., 2020), (Shnapp, Paci, & Bertoldi, 2020). According to an EU wide survey (European Commission, 2019), the vast majority of consumers find that energy renovations are too expensive: they do not wish to finance these measures through loans or mortgages. Moreover, precise and easily understandable information on existing and forthcoming financing mechanisms is often missing. As a result, consumers are often not aware of the financial support available (Zangheri, et al., 2020).

[23] This number shows the yearly renovated floor area

The unwillingness to invest in thermal renovation is related to another significant barrier, namely the lack of awareness of the benefits of thermal renovation. Building renovation brings multiple benefits, such as reduced energy bills, improved indoor air quality and a higher comfort level for households. Since consumers often lack information regarding the quantification of these benefits, they cannot evaluate the financial benefit of investments. Moreover, when it comes to privately rented buildings, multi-apartment buildings, social housing units and leased commercial buildings, split incentives are a well-known barrier to freezing investments in energy efficiency upgrades (Castellazzi, Bertoldi, & Economidou, 2017). Split incentives are common barriers because the investment flows and benefits of the investments are not properly divided between building owners and tenants. Interestingly, an EU wide survey has shown that consumers from countries in eastern and southern Europe report frequently that overly strict regulations have posed a barrier to investment in energy renovations (European Commission, 2019).

Other barriers not discussed are technical issues in the urban environment, national and local regulations and permitting, secondary legislation and local rules, and the gearing up of markets to deliver according to the expected deployment.

The challenge for policymakers is to address these barriers with policies targeted at various stakeholders and types of renovation. According to the NECPs, economic support for thermal renovation is one of the more prominent policy instruments in the heating and cooling sector in Member States (Toleikyte & Carlsson, 2021). When designing policy measures, the following aspects can be taken into account.

- To overcome the barrier of high investment costs, targeted loans or grants are an option. According to an EU wide survey, negative attitudes towards loans are significant, particularly in older cohorts. On the other hand, 'grants, loans etc.' are described as a very strong incentive to overcome financial barriers. As grants and loans are asked about in the same question, it can be assumed that people prefer grants over loans (European Commission, 2019).
- Financial instruments could be linked with energy building codes, where incentives are awarded to projects achieving energy performance levels beyond current code levels, or a certain energy class under the national energy performance certification scheme (Bertoldi, Economidou, Palermo, Boza-Kiss, & Todeschi, 2020).
- To overcome regulatory barriers and high transaction or indirect costs such as inconvenience for residents, policy measures should make full use of certain events as trigger points for renovation, e.g. on sale or change of tenancy of a home. Because these events occur infrequently, such policies are urgently required, so that these least-cost opportunities are not missed (CE Delft, 2020).
- National LTRS (long-term renovation strategies): the compliance and ambition of national LTRS should be increased by Member States, boosting the annual deep renovation rate. Moreover they should link policy actions to their benefits (increased renovation rates and reduced GHG emissions) (BPIE, 2021a).
- Existing strategic long-term tools impacting the building sector such as the comprehensive assessments of heating and cooling (Energy Efficiency Directive (EED) Article 14) and national Long-Term Renovation Strategies (LTRS, EPBD Article 2A) should be better linked to each other (BPIE, 2021a).

9.5 Policymaking challenges for increasing the switch to low-carbon heating

This report focuses on existing buildings and concludes that by 2030, at least 40 million existing dwellings should switch their fossil fuel boilers to low-carbon heating alternatives. Most of the scenarios analysed in this report have revealed little or no future role for fossil fuels in the buildings sector (see Chapter 5). An almost complete coal phase-out by 2030 is shown in the EC IE MIX and LCEO Zero Carbon scenarios, while all scenarios show a complete phase-out by 2050. The use of oil is modelled to be reduced by 80% by 2030 compared to complete phase-out in the most ambitious scenario. Although all scenarios see a reduction of natural gas by 2030 and 2050, the respective numbers vary significantly (up to 45% reduction of natural gas by 2030 and between 65% and 100% by 2050).

Although the use of fossil fuel in buildings dropped by over 16% in the period 2000-2019, energy consumption in the EU buildings sector is still currently heavily based on fossil fuels (see Chapter 3). In residential buildings, gas covers 32% of final demand, followed by oil (11%) and coal (4%). Electricity (25%)

and renewables (19%) also play an important role. The service sector is dominated by electricity (49%), followed by gas (28%) and oil (8%). Some of the barriers that might influence a slow increase in renewables in the heating and cooling sector are (Toleikyte & Carlsson, 2021):

- that natural gas is used as a transition fuel for coal;
- the lack of indigenous resources and infrastructure;
- the dispersion of housing/inhabitants in rural areas;
- that natural gas is the most cost-effective investment compared to other heating technologies (with current gas prices as an exception);
- the untapped potential due to missing long-term energy planning.

To ensure a smooth transition, a combination of actions is required in several sectors: building renovation, a shift away from fossil fuel-based boilers to renewables (in both individual and central heating), and the integration of heating into the electricity sector. Efficiency of buildings is crucial for using low and zero-carbon heating systems (efficient heat pumps, biomass boilers, solar thermal and centralised energy supply) to operate at high performance. Otherwise, these systems, combined with non-efficient buildings, are inefficient and expensive (Agora Energiewende, 2019), (Rosenow & Lowes, 2020). Some scholars envisage an increasingly important role for district heating, especially in urban areas. District heating enables high levels of energy efficiency, renewable energy and sector coupling as well as the integration of waste heat (Mathiesen, et al., 2019), (Agora Energiewende, 2019).

This report focuses on the reduction of fossil fuels for two reasons. First, there is a much higher convergence among studies on the reduction of fossil fuel. Second, we have not compared the alternative low-carbon heating systems. The main challenge for the coming years is that these reductions in fossil fuel use, and related greenhouse gas emissions, must happen soon.

10 Conclusions

This study provides some light and data on the challenges of reducing the consumption of fossil fuels in buildings. We quantify the role of renovations of heating systems that involve a switch from fossil fuels to low-carbon alternatives. Our main conclusions are as outlined below.

- Today, around 60% of heating systems and dwellings are fossil-fuel based. When including heat pumps and other electric heating, 75% of dwellings rely on fossil fuel for their heating needs. Natural gas, oil and coal provide respectively 38%, 15% and 4% of the final energy for EU space heating in residential buildings.
- By 2030, based on all scenarios covered, the reduction of carbon emissions from buildings is 40% when compared to 2019; this equals the reduction that took place in the last 30 years. By 2040, the reduction is 75% by 2040, also compared to 2019.
- We should be more explicit when we discuss the nature of renovations. They could be divided into three groups: ENVELOPE ONLY renovation, HEATING ONLY renovation and COMBINED renovation, which is a combination of both. In the period 2026-2030, the annual rate of renovations that switch fuel to low-carbon heating systems is projected to reach 2.5% of the stock. Enhanced policies on the intelligent replacement of heating systems would be helpful, because the greatest impact on CO_2 reduction is made by converting fossil heating systems, mostly to heat pumps.
- Our analysis reduces uncertainty about how fast the EU needs to change its fuel mix in buildings. If renovation actions are delayed and only start to have effect in 2026, the risk is that the renovation rate would need to increase too quickly.
- We recommend the harmonisation of residential heating technology options with the 2030 climate goals. Revised Ecodesign or Energy Labelling standards for new heating systems could be a potential means of supporting the phase-out of fossil-fuel boilers.
- The discussions should extend beyond ENVELOPE ONLY renovations. Envelope renovations which do not switch fuel to low-carbon heating should be avoided after around 2025 for dwellings currently using oil/coal and soon after 2030 for dwellings using natural gas.
- Building renovations will affect 30% of households by 2030 and more than 85% by 2050. By 2030, 60% of coal and oil boilers should be gone, and one in four natural gas boilers. This will require deep renovations and a doubling of the number of dwellings on heat pumps and district heating by 2030 if biomass remains more or less unchanged. When using hybrid technologies (electric heat pump and fossil fuel boiler), the number of dwellings switching away from natural gas needs to be around 25% higher.
- A 60% average reduction of oil use by 2030 requires that the replacement rate of residential oil boilers needs to increase to 7% by 2025. The current rate in Germany is 3.4%. Oil boilers should only be replaced by low-carbon heating systems; and this should become the norm as soon as possible. We propose the investigation of further options for incentives to retire oil heating devices, even when they don’t yet need to be replaced from a technical point of view.
- In the period 2022-2030, low-carbon heating is projected to be introduced into more than 15 million dwellings (about half) currently using oil or coal and in around 25 million dwellings (one in four) currently using natural gas. By 2030, the market for envelope renovations doubles and the market for heating system renovations triples, consisting almost entirely of low-carbon alternatives.
- According to our estimates, the annual replacement of gas boilers with new gas boilers reduces from 3.7 million per year today to around 1.1 million by 2025. This can only occur if the low-carbon heating technology market grows fast enough to fulfil the remaining 2.6 million replacements. This reduces the market size of new gas boilers from 4 billion today to below 1.5 billion in 2025.
- A 30% average reduction of gas use by 2030 requires the removal of gas boilers in 25% of dwellings that currently use gas. As of 2026, the installation of new gas boilers should be marginal. The rate of replacement of gas boilers with non-fossil fuel systems can remain lower than the default replacement rate (3.5%) but if actions are delayed, the rate must accelerate very fast to 4.8% from 2025 to make up for lost time. If replacement to low-carbon heating is not addressed as soon as possible, it becomes very difficult to reach the 2030 ambition.

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List of abbreviations and definitions

CCS	Carbon Capture and Storage
CCU	Carbon Capture and Use
CTP	2030 Climate Target Plan
DH	District Heating
DHC	District Heating and Cooling
EED	Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, OJ L 315, 14.11.2012, p. 1–56
EGD	European Green Deal
EPBD	Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings OJ L 153, 18.6.2010, p. 13–35
ETS	Emissions Trading System
GHG	Greenhouse gas
H&C	Heating and Cooling
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land-Use Change and Forestry
MEPS	Minimum Energy Performance Standards
Mtoe	Million tonnes of oil equivalent
NECP	National energy and climate plan
REDII	Directive (EU) 2018/2001of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, OJ L 328, 21.12.2018, p. 82–209
RFNBO	Renewable fuel of non-biological origin, according to Article 2(63) of the Renewable Energy Directive. This includes for instance renewable hydrogen and hydrogen based synthetic fuels.

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Annex 1 Overview of studies and selected scenarios

Publisher	Study	Year	Scenario	Abbreviation	Reference
British petroleum	Energy Outlook 2020	2020	Rapid	bp Rapid	(bp, 2020)
			Net Zero	**bp Net Zero**	
			Business as usual	Bp BAU	
DNV	European Carbon Neutrality: The Importance of Gas	2020	Eurogas	**DNV Eurogas**	(DNV GL, 2020)
European Commission	Delivering the EU Green Deal	2021	Reference 2020	EC REF	(European Commission, 2021a)
			REG	EC REG	
			MIX	**EC MIX**	
			MIX-CP	EC MIX-CP	
European Climate Foundation	Net Zero by 2050: From Whether to How	2018	Technology	ECF Technology	(European Climate Foundation, 2018)
			Demand-focus	**ECF Demand-focus**	
			Shared effort	ECF Shared effort	
EBB/CAN	Paris Agreement Compatible Scenarios for Energy Infrastructure	2020	EEB/CAN PAC	**EEB/CAN PAC**	(EBB/CAN, 2020)
Fraunhofer ISI	GHG-neutral EU2050 – a scenario of an EU with net-zero greenhouse gas emissions and its implications	2019		Fraunhofer ISI - GHG neutral	(German Environment Agency, 2019)
International Energy Agency	World Energy Outlook 2020	2020	New Policies Scenario	IEA WEO NPS	(IEA, 2020)
			Current Policies Scenario	IEA WEO CP	

			Sustainable Development Scenario	**IEA WEO SDS**	
Teske et al. 2019	Achieving the goals of the Paris Agreement	2019	5C	IFS 5C	(Teske, 2019)
			2C	IFS 2C	
			1.5C	**IFS 1.5C**	
Joint Research Centre	Global Energy and Climate Outlook 2020	2021	Reference	JRC GECO Ref	(Keramidas, et al., 2021)
			2C	JRC GECO 2C	
			1.5C	**JRC GECO 1.5C**	
	Low Carbon Energy Observatory	2018	Baseline	LCEO Baseline	(Nijs, Ruiz Castello, Tarvydas, Tsiropoulos, & Zucker, 2018)
			Diversified	LCEO Diversified	
			ProRes	LCEO ProRES	
			Zero Carbon	**LCEO Zero Carbon**	
Navigant	Gas for Climate	2019	Minimal gas	Navigant min gas	(Navigant, 2019)
			Optimised gas	**Navigant opt gas**	
Oeko-Institut	The Vision Scenario for the European Union	2017	Reference	Oeko Ref	(Dr. Felix Chr. Matthes, 2017)
			Vision	**Oeko Vision**	

Annex 2 Overview of the methods deployed and their scope in energy scenario studies

Organisation	Study	Method/model	Scope			
			Geographical	Temporal	Sectoral	Emissions
British petroleum	bp Energy Outlook 2020 edition	Top-down simulation model	Global, US, Brazil. EU, Russia, Middle East, Africa China, India, Other Asia	Up to 2050	Power Industry Buildings Transport	Energy-related CO_2, LULUCF and non-CO_2
DNV	European Carbon Neutrality: The Importance of Gas	DNV GL ETO system-dynamics feedback model (based on Stella)	EU28 plus Iceland, Liechtenstein and Norway	Up to 2050	Power Industry Residential Services Transport Other	Energy-related CO_2 (incl. international aviation)
European Commission	Package of proposals on Delivering the EU Green Deal	PRIMES (partial equilibrium optimisation model for the energy system), POLES-JRC (for the global context on fossil fuel prices), GEM-E3 and E3ME (for macro-economic analysis) GLOBIOM and CAPRI (for LULUCF) GAINS (for non-CO_2 GHG emissions and air pollution)	EU27, country level (results presented at an EU27 level)	5-year time step, up to 2050 (optimisation up to 2070), results available for 2030 and 2050	Power Industry Residential Transport Tertiary (i.e. services, agriculture, fisheries and other)	Energy-related and process CO_2 (incl. international aviation), LULUCF and non-CO_2

European Climate Foundation	From Whether to How (2018)	Techno-economic simulation model (CTI Roadmap tool extended for Europe), which simulates emissions and mitigation options. Similar calculator tools are used in several projects (e.g. EUCalc, DECC-UK, CLIMACT-BE)	EU28	5-year time step, up to 2050	Power Industry Buildings Transport	Energy-related and process CO_2 (incl. international aviation), LULUCF and non-CO_2
EEB/CAN	Paris Agreement Compatible Scenarios for Energy Infrastructure	bottom-up desk research, including as comparing and adopting elements of a multitude of existing studies and models, taking into account feedback of 150 stakeholders	EU28	5-year time step, up to 2050	Power Industry Transport Residential Services Agriculture	Energy-related and process greenhouse gas emissions (CO_2eq, without LULUCF)
Fraunhofer ISI	GHG-neutral EU2050 – a scenario of an EU with net-zero greenhouse gas emissions and its implications	Bottom-up projections based on decomposition analyses, model results (older) and full sector modelling (typically partial-equilibrium optimization models).	EU28	2050 only	Power Industry Transport Buildings Other	Energy-related and process greenhouse gas emissions (including LULUCF)
International Energy Agency	World Energy Outlook (2020)	World Energy Model (WEM), a large-scale simulation model consisted of three main modules (final energy consumption, energy transformation and energy supply)	Global, public results on 21 regions, including the EU28 (model has 25 sub-regions)	Annual steps up to 2040	Power Industry Buildings Transport Other (agriculture and other)	Energy-related (incl. international aviation at global level) and process CO_2

Sven Teske et al.	Achieving the Paris Climate Agreement Goals (2019)	GQW (non-CO_2 GHG statistical analysis) MAGICC (climate change) TRAEM (transport) EM (simulation energy system) [R]E 24/7 (power system balancing) [R]E SPAVE (regional wind and solar potential) Land-based sequestration design (Monte Carlo carbon sequestration) No cost-optimisation objective functions	Global, 10 main sub-regions, including OECD Europe (energy system model)	Up to 2050	Power Industry Residential and other (aggregated) Transport	Energy-related CO_2 (incl. international aviation at global level), LULUCF and non-CO_2
Joint Research Centre	Global Energy and Climate Outlook (2020)	POLES-JRC, partial equilibrium simulation model on energy system and GHG forecasting and the computable general equilibrium model RC-GEM-E3 on the economic impacts of the developed scenarios	Global, 66 countries/regions including the EU28	Annual steps, up to 2050/70	Power Industry Buildings Transport Agriculture Other	Energy-related and process CO_2 (incl. international aviation at global level), LULUCF and non-CO_2
Joint Research Centre	Low Carbon Energy Observatory (2019)	JRC-EU-TIMES, partial equilibrium optimisation model for the energy system	EU28, country level (and neighbouring countries)	Gradually increasing from 2 to 10 years up to 2050	Power Industry Residential Services Transport Agriculture	Energy-related and process CO_2 (incl. international aviation)

Navigant	Gas for Climate (2019)	Navigant Energy System Model, a cost-optimisation model built using Analytica software with various dedicated modules on renewable and low-carbon gas supply, end-use sectors, power transformation and infrastructure	EU28	Results only for 2050	Power, Industry (steel, ammonia and methanol production), Buildings (heating), Transport (passenger cars, freight trucks, buses, ships and aircrafts)	Energy-related and process CO_2 (incl. international aviation)
Oeko Institut	The Vision Scenario for the European Union (2017)	Top-down analysis of energy consumption and GHG emission dynamics for final energy, process CO_2 emissions, and non-CO_2 emissions (except transport). Bottom-up analysis for power and transport. Oeko Institute uses the ELIAS (in-house lowest capital cost model for the power sector) combined with the PowerFlex electricity market model. Unclear if they were also used in the 2017 exercise. Economic optimisation on a qualitative basis (not based on analytical modelling)	EU28	2030, 2040 and 2050	Power Industry Residential Transport Tertiary	Energy-related and process CO_2 (incl. international aviation) and non-CO_2

Annex 3 National policies and measures towards building's decarbonisation

When it comes to national policies, there exist big differences between the Member States. Table 3 shows targets for three areas namely, phase-out fossil fuels, increase the use of RES and objectives addressing building renovation. These targets were provided by the Member States in their National Energy and Climate Plans (NECPs) submitted to the European Commission in 2019.

Table 6 National policies and measures towards building's decarbonisation (presented by the MSs in their NECPs (source: NECPs cited in (Toleikyte & Carlsson, 2021))

Member State	**Concrete objectives to phase-out fossil fuels**	**Concrete objectives to increase the use of RES**	**Concrete objectives for building renovation**
Belgium	Phase out of back-up coal in residential sector by 2030, start exit from heating oil from 2025, start exit from natural gas in 2030 (in Brussels).		
Germany	The majority of district heating generation from coal-fired cogeneration plants will be eliminated by 2030.		
Estonia		TWh (946 ktoe) of the total heat demand shall be covered by biomass in 2030. The share of RES in district heating shall reach 80% in 2030	until 2030: ≥ 40%: Share of small residential buildings from the total building stock with energy performance indicator class is at least C or D. ≥ 50%: Share of small apartment buildings from the total building stock with energy performance indicator class is at least C.
Ireland	A shift to alternative heating sources, with targets of 600,000 heat pumps installed over the period 2021-2030. A ban of the installation of oil boilers from 2022 and the installation of gas boilers from 2025 in all new dwellings. Progressively phase out oil and gas boilers in existing dwellings		Retrofitting social dwellings which are more than 40 years old (30% of the social housing stock). Improvement of the energy efficiency of the building stock with a target of 500,000 existing buildings by 2030.
Spain			Targets for energy renovation of buildings up to 2030: Energy efficiency improvement (thermal envelope) over the decade of a total of 1,200,000 dwellings
Latvia			At least 2000 residential multi-apartment buildings and at least 5000 private homes will be renovated between 2020 and 2030. This also includes an installation of RES technologies (non-emission technologies) or a connection

Member State	Concrete objectives to phase-out fossil fuels	Concrete objectives to increase the use of RES	Concrete objectives for building renovation
			to the district heat network.
Lithuania		A replacement of 50,000 inefficient boilers with heat pumps or efficient district heating each year. Installation of new RES boilers, installed capacity 200 MW until 2030.	By 2030, the target is to renovate 5000 MFH and 500 yearly (equal to 750,000 m^2 area).
Luxembourg			Renovation objective for the existing housing stock: 3% renovation rate at 72% renovation depth on average.
Hungary		By 2030, at least 200,000 households shall have roof-mounted solar panels with an average power of 4 kW. Hungary´s objective is to reduce the gas import ratio to close to 70% by 2030 by reducing energy consumption and increasing domestic production.	
Netherlands	Cannot connect new houses to gas network from 2020, and 1.5 million homes should have switched from gas by 2030.		
Austria	The target is to replace half of the existing 700,000 oil-boilers by 2030.		doubling of the 'thermal renovation rate' is envisaged for the period 2020-2030
Slovenia	Phasing out coal: at least 30% by 2030 and the decision not to use coal in Slovenia according to the principles of a just transition to 2021. A ban on the sale and installation of new heating oil boilers until 2023.		
Slovakia	At the latest in 2021, ban heating oil in new construction; ban the sale and installation of new boilers fired with heating oil in 2023.		
Finland	Phasing out the use of coal in energy production by 2029. Finland will phase out the use of fossil fuel oil in heating by the start of the 2030s.		

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