Towards EU climate neutrality

Progress, policy gaps and opportunities

Chapter 7: Buildings

Assessment Report 2024

European Scientific Advisory Board on Climate Change

Contents

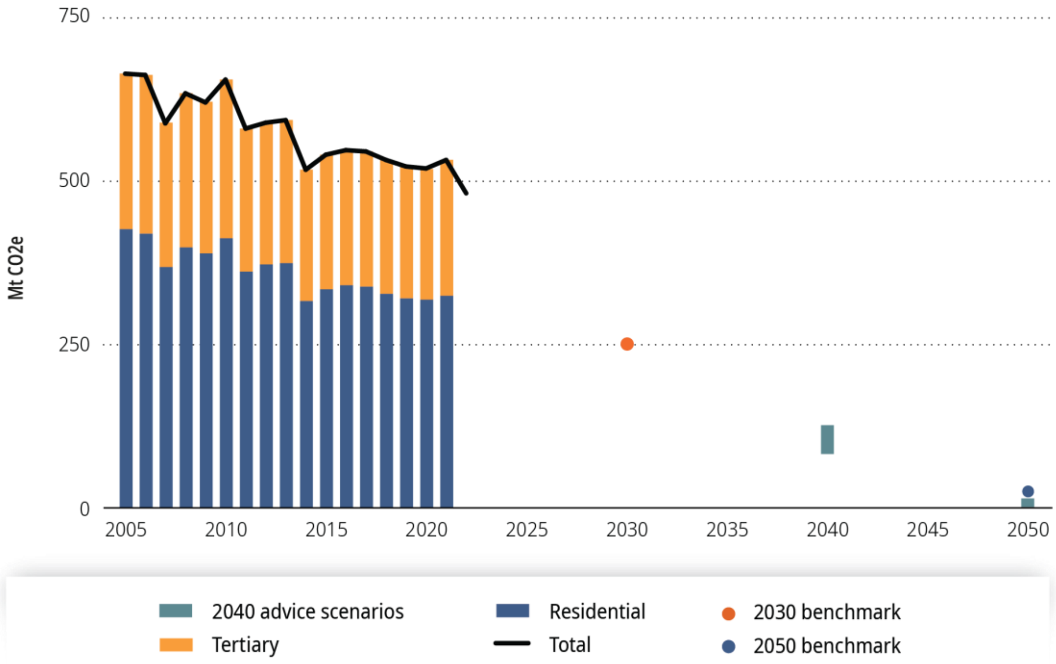
7 Buildings

Key messages

The GHG emission trend in the EU buildings sector is not in line with the EU's climate objectives. Putting it on track towards climate neutrality can be accelerated by a shift to zero-emission buildings and deep energy retrofits of existing buildings, combined with reducing the floorspace and energy demand.

GHG emissions in the buildings sector have decreased by 27.5 % (– 11 Mt CO_2e per year on average) between 2005 and 2022 (Figure 45). However, to be consistent with the European Commission's scenarios that underpin the overall 2030 – 55 % objective, the average rate of GHG emission reductions would need to almost triple in 2023–2030 to 31 Mt CO_2e per year. Achieving that scale of emission reductions in the coming years requires a deep energy retrofit of the EU building stock in combination with a rapid switch from fossil to zero- or low-carbon heating technologies.

Figure 45 Indicator B1 – overall progress in reducing GHG emissions from the EU tertiary and residential buildings



Sources: See Figure 47.

The rate and depth of renovation must increase fast while managing distributional impacts.

Needs. Around three quarters of EU buildings were built before 1990. Most of the buildings (85–95 %) standing in the EU today will also be there in 2050. Around 75 % of buildings in the EU are energy inefficient. Improving the energy performance of the existing buildings can reduce the final energy demand, but the pace and depth of building energy retrofits so far is not sufficient to meet the EU's climate targets by 2030 and 2050. The EU needs to overcome multiple barriers to deep energy retrofits, including stifled price signals, split incentives ([1]), and obstacles linked to the building sector's high heterogeneity in terms of building types, sizes and operational uses. In addition, skills shortages are acute in the construction sector (see Chapter 15 'Labour, skills and capacity building'). Policy design needs to account for the socioeconomic impacts of measures to decarbonise buildings in the context of a just transition (see Chapter 11 'Whole-of-society approach').

Gaps. EU policies so far have not overcome barriers to wide-scale and deep energy retrofits of buildings **(implementation gap)**. The recast of the EPBD aims to address this gap, notably through the gradual introduction of minimum energy performance standards to trigger renovation of the worst-performing buildings, a definition of deep renovation and the introduction of building renovation passports. The introduction of the EU ETS 2 covering energy use in buildings will support energy retrofits but is not in itself a solution to the persisting barriers. Constraints on distribution, organisation, administrative capacity, investment, and data go beyond the insufficient price signals. The quality and ambition of the EU's long-term renovation strategies are not sufficient to guide the required building renovation towards the 2050 climate neutrality objective **(implementation gap)**.

Recommendation B1. The EU ETS 2 should be accompanied by the swift adoption and effective implementation of an ambitious EPBD recast addressing:

- organisational, administrative capacity and investment barriers, for instance through one-stop shops and energy performance contracting,
- regressive socioeconomic impacts, such as through the Social Climate Fund and actions set out in the European Commission's Recommendation (EU) 2023/2407 of 20 October 2023 on energy poverty (see Chapter 11 'Whole-of-society approach')
- skilled workforce availability (see Chapter 15 'Labour, skills, and capacity building').

Recommendation B2. The long-term renovation strategies should be improved and contribute to the national LTSs under the EU climate Governance Regulation (see Chapter 14 'Climate governance').

In most cases, decarbonisation of heating and cooling is most efficiently achieved through direct electrification based on the accelerated deployment of heat pumps. District heating has also an important role to play.

Needs. Fossil fuels and biomass dominate the heating sources for the EU's building stock. Space heating and water heating represent around 80 % of the building energy demand across the EU. Heating, cooling, ventilation, and hot water solutions in the EU building stock need to reflect the changing climatic conditions, advancements in net zero technologies, and direct electrification benefits from efficiency and system perspectives. Heat pumps deliver heat at a higher efficiency than combustion fuel boilers and usually rely on increasingly renewables-dominated electricity grid supply. Very efficient appliances reduce energy demand and hence reduce the need for expanding electricity supply. The EU needs to keep up the momentum created by the energy crisis, which led to a massive uptake of heat pumps.

Gaps. So far, EU policies have been moderately successful in driving non-fossil fuel switching. This is thanks to, among other factors, subsidies to fossil gas allowed under the ETD and EU State aid rules **(policy inconsistency)**, a lack of system integration (see Chapter 4 'Energy supply') and insufficiently robust EU standards leading to incremental energy efficiency improvements and lock-in effects **(policy gap)**.

([1]) A split incentive may occur in the case of rented properties, that is, principal/agent problems in which the tenant benefits from the decarbonisation investment made by the landlord.

Recommendation B3. To maintain the current rate of heat pump uptake and, where relevant, shift to innovative district heating, EU policies should create a conducive framework including carbon pricing, energy taxation (see Chapter 10 'Pricing emissions and rewarding removals), energy system integration guided by the energy efficiency first principle (see outcome 1 subsection below and Chapter 4 'Energy supply') and robust supply chains including available skilled workforces (see Chapter 15 'Labour, skills, and capacity building'). It should support timely and robust local heating and cooling plans, which are required under the EED. The roll-out of heat pumps should be considered in the context of better-integrated social and climate policies (see Chapter 11 'Whole-of-society approach').

Reducing the demand for energy and materials over the life cycle of buildings is an important lever for a fair and just transition. To this end, EU policies can provide information and guidance to national policies, for example in the field of taxation and planning.

Needs. Buildings' energy and materials demands have been increasing overall, as a result of changes in demography, climatic conditions and use of building. The EU's **floor area** has been increasing more than could be justified by the EU's population growth. Reducing the demand for energy and materials, known as sufficiency, relies on widely available measures such as compact cities, shared spaces, voluntary demand reduction, and nature-based solutions such as green roofs that can bring multiple benefits including climate resilience and well-being. In this respect, sufficiency-led **reduction of floor space demand** is one of the most impactful measures to reduce buildings' environmental footprint, including embodied energy and carbon.

Gaps. The revised EED and the EPBD before recast do not explicitly aim to leverage sufficiency, but include provisions that will encourage it, such as the consumer information and empowering programmes. The EU does not prominently guide urban/spatial planning and taxation towards energy and material sufficiency **(ambition gap)**. The EPBD recast aims to tackle buildings' embodied carbon and energy, which could encourage better use of existing buildings rather than new construction.

Recommendation B4. The EU should strongly encourage reduction in demand for energy and materials by promoting sufficiency in the pre-use phase, that is, through urban and territorial spatial planning and building codes, as well as the use phase, that is, through digital solutions, awareness-raising and sharing good practice, for example on land value taxation, and through adequate carbon pricing under the EU ETS 2 (see Chapter 10 'Pricing emissions and rewarding removals'). Innovative policy measures could also incentivise building occupants' behaviour to drive energy and resource savings through, for example, energy saving feed-in tariffs and personal carbon allowances, perhaps based on experience from regulatory sandboxes, since a large proportion of emissions comes from the building operations phase.

Reliable, granular and comparable data on building performance and on the multiple benefits of energy efficiency investment are urgently needed to underpin policy measures.

Needs. When embedded in appropriate policies, reliable building performance data can contribute to (i) attracting private investment, (ii) creating new markets and infrastructure, (iii) innovating to reduce building life cycle emissions, (iv) spurring behavioural changes and (v) better tracking of EU policy progress. The EU increasingly relies on energy performance certificate (EPC) data for tracking the progress and implementation of renovation policies and funding.

Gaps. So far, EU policies have not sufficiently facilitated collection and sharing of reliable, granular, comparable and interoperable information on the energy performance, investments in energy efficiency and multiple benefits of efficient building stock, such as indoor air quality **(policy gap)**. The EPC schemes are of uneven quality and have limitations in terms of reliability, as they are based on data derived from the physical properties of buildings rather than energy demand driven by occupancy behaviour **(ambition gap)**. The recent EPBD recast aims to address this gap.

Recommendation B5. The EPBD recast and follow-up to the EU action plan on digitalisation of energy system should allow better use of the EPCs and minimum energy performance standards and should make it possible to unlock the benefits of data in the context of energy system integration (see Chapter 4 'Energy supply'). The EPBD recast should be implemented swiftly so that national databases on the energy performance of buildings are established and the role of the EU Building Stock Observatory is reinforced. The data collected should be based on actual performance and go beyond the energy parameters, so it includes at least environmental quality, thermal comfort, sufficiency and circularity, as well as building resilience aspects. This should help improve the policy narratives accompanying building decarbonisation measures (see also Chapter 11 'Whole-of-society approach').

7.1 Scope and sectoral assessment framework

Scope

This chapter covers all residential and tertiary buildings. In tracking progress, it covers all direct emissions from fuel combustion in buildings, and energy-related emissions from the agricultural sector. Emissions from district heating and the production of electricity that is used in buildings are covered in the energy supply sector. Emissions from the construction and maintenance of buildings, and F-gases from heating and cooling installations, are reported in the industry sector. For policy consistency, this chapter also considers the role of buildings in the broader energy system.

Greenhouse gas emission reductions required in buildings to reach climate neutrality

Under the 1.5TECH and 1.5LIFE scenarios of the European Commission's in-depth analysis accompanying the 2018 LTS 'A clean planet for all' (EC, 2018e), and under the more recent MIX scenario of the 2020 climate target plan impact assessment (EC, 2020s), buildings sector emissions are reduced by approximately > 95 % by 2050 compared with 2005. The very few remaining emissions in 2050 need to be counterbalanced by emission removals to achieve overall climate neutrality. This is also in line with the latest IPCC AR6 illustrative mitigation pathways, which show deep reductions from buildings in most scenarios by 2050 (IPCC, 2022b).

Assessment framework for the buildings sector

The following building blocks were identified to achieve the required GHG reductions in the buildings sector by 2050.

Outcomes. Based on the latest IPCC assessment report, the following two outcomes were identified as a basis for tracking progress and policy consistency in the buildings sector (IPCC, 2022b):

— **lowering energy and material demand**
— shifting towards **efficient and decarbonised energy supply**.

Mitigation levers. To achieve these outcomes, and building on the IPCC approach, the assessment of the EU policies relevant to buildings follows the sufficiency, efficiency, renewables framework (IPCC, 2022b). **Sufficiency** can be understood as reducing the demand for energy services and materials, often through better use of existing space or the building materials, **efficiency** as continuous short-term marginal technological improvements, and **renewables** as reducing the environmental impacts of supplying energy and materials.

In this context, the following levers for the contribution of buildings to the EU's overall GHG emission reductions have been identified.

- **Deep retrofits and zero-emission new buildings.** Thermal efficiency retrofits of existing envelopes should be followed up by replacing the heating, ventilation and air conditioning and backed up with demand-side measures through digitalisation and the integration of renewable energy, retrofits and new builds in line with zero-emission building standards, in other words buildings with very high energy performance. The remaining energy demand should be covered mainly by local RESs.
- **Heat pumps.** Switch fuel to renewable heating and cooling through heat pumps, and highly efficient district heating, solar thermal, geothermal and sufficiency-led cooling solutions such as indirect evaporative cooling.
- **Energy and material sufficiency.** Reduce demand for space and resources, for example by downsizing dwellings and increasing co-habitation. Make better use of available floorspace rather than construct new buildings.
- **Sustainable construction.** This has a strong link to material sufficiency. Consider and reduce buildings' embodied carbon and emissions, notably through, for example, extending the lifespan of existing buildings while increasing the intensity of building use, reducing the amount of materials required for each unit of newly built floor area (material efficiency), use innovative construction materials and reduce the GHG intensity of material production.

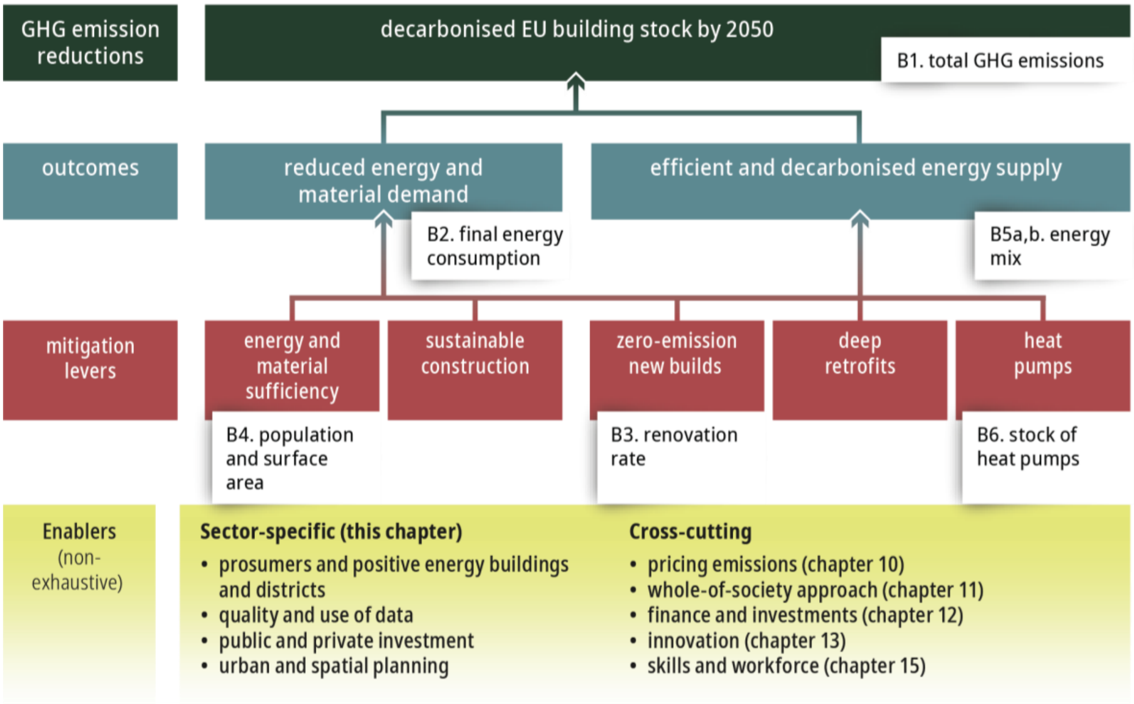
While the EU 2050 vision suggests renewable **hydrogen** and hydrogen blends with fossil gas have a role to play in heating buildings (EC, 2018d), the IPCC warns against it because 'the delivered cost of heat from hydrogen would be much higher than the cost of delivering heat from heat pumps, which could also be used for cooling. Repurposing gas grids for pure hydrogen networks will also require system modifications such as replacement of piping and replacement of gas boilers and cooking appliances, a factor cost to be considered when developing hydrogen roadmaps for buildings. There are also safety and performance concerns with domestic hydrogen appliances … scenarios assessed show a very modest role for hydrogen in buildings by 2050' (IPCC, 2022g).

Enabling conditions. In addition, seven enabling factors have been identified as key to at least one of the mitigation levers described above. They are finance and investments, quality and use of data, prosumers and positive energy buildings and districts, pricing emissions, skills and workforce, whole-of-society approach and innovation. Some of these enabling conditions are assessed in other chapters throughout the report, as shown in Figure 46. The four sector-specific enablers addressed in this chapter are:

- **urban and spatial planning**, for example design of urban and rural settlements enabling reduced demand for floor space, faster deployment of renewables and better adaptive capacities;
- **prosumers and positive energy buildings and districts**, for example adapting electricity grids through infrastructure investment facilitating access to the grid, and enabling buildings to have an active role in electricity system reliability (demand response) through digital and smart solutions integrating energy storage systems, such as on-site batteries and seasonal heat storage;
- **quality and use of data**, for example improving the availability, quality and use of EPCs, digitalising buildings data systems, and integrating data on the multiple benefits of building retrofits into investment decision-making;
- **public and private investment**, for example better use of public funds with a focus on additionality and alleviation of negative socioeconomic impacts; technical assistance and one-stop shops for the crowding-in of private funding; support to sufficiency; and fiscal incentives led by a just transition.

The assessment framework for the buildings sector, including the selected indicators to track progress for this sector (see white boxes), is shown in Figure 46.

Figure 46 Assessment framework for the buildings sector



Source: Advisory Board (2024).

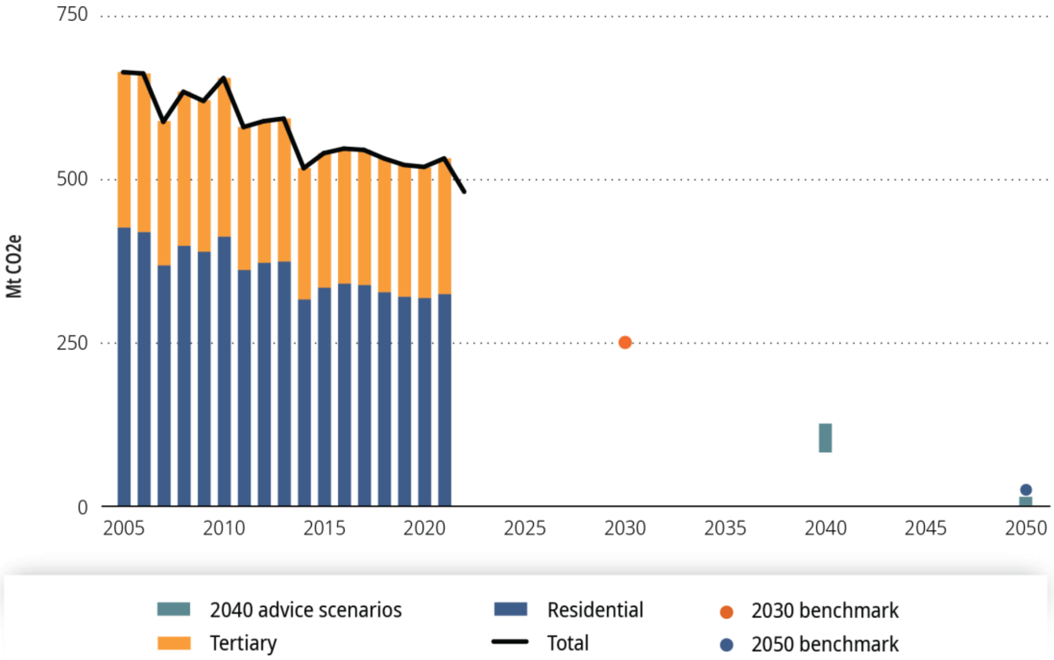
7.2 Emission reduction progress

GHG emissions in the buildings sector ([2]) decreased by 27.5 % (– 11 Mt CO_2e per year on average) between 2005 and 2022. Despite consistent emission reductions since 2005, the sector is not on track compared with the European Commission scenarios that underpin the EU 2030 climate target. The buildings sector's contribution would require the average rate of GHG emission reductions to almost triple in 2023–2030 (to – 31 Mt CO_2e per year) compared with 2005–2022 (see Figure 47).

The emission reduction so far is primarily a result of decarbonising the energy mix and in particular a reduction in the use of oil products (Eurostat, 2023e). Energy is being used more efficiently in buildings (see indicator B4 below), but these efficiency gains are counteracted by shrinking household sizes, more floor area per person (see indicator B3), more electric appliances and increased demand for energy services driven by economic activity. The emission reductions required from the buildings sector by 2030 can be achieved through an accelerated deep energy retrofit of the European building stock in combination with a rapid switch from to efficient, non-fossil heating and cooling technologies.

([2]) This refers to emissions from energy use in the residential sector, the commercial sector (which includes institutions and public services) and agriculture. Although agriculture is not the focus of this chapter, these agricultural emissions are included for comparability with the European Commission analysis, which aggregates energy-related emissions from the three sectors. According to the EU GHG inventory, agriculture has accounted for 6–7 % of these emissions historically.

Figure 47 Indicator B1 – overall progress in reducing GHG emissions from the EU buildings sector



Notes: Historic data refers to GHG emissions from residential and tertiary sectors (including energy use in agriculture) from the EU GHG inventory. 2030 benchmark refers to residential & tertiary CO_2 emissions from the Fit for 55 MIX scenario. 2040 advice range refers to energy-related CO_2 emissions in the residential and tertiary sector in the scenarios that underpin the Advisory Board's 2040 advice, with original data (which does not include agriculture) adjusted upwards for comparability with the other series (assuming the share of agricultural energy in overall emissions from these sectors remains at the 2021 level as per GHG inventory). 2050 benchmark refers to residential and tertiary sector CO_2 emissions reported in the in-depth analysis accompanying A Clean Planet for All, recalibrated for EU27.

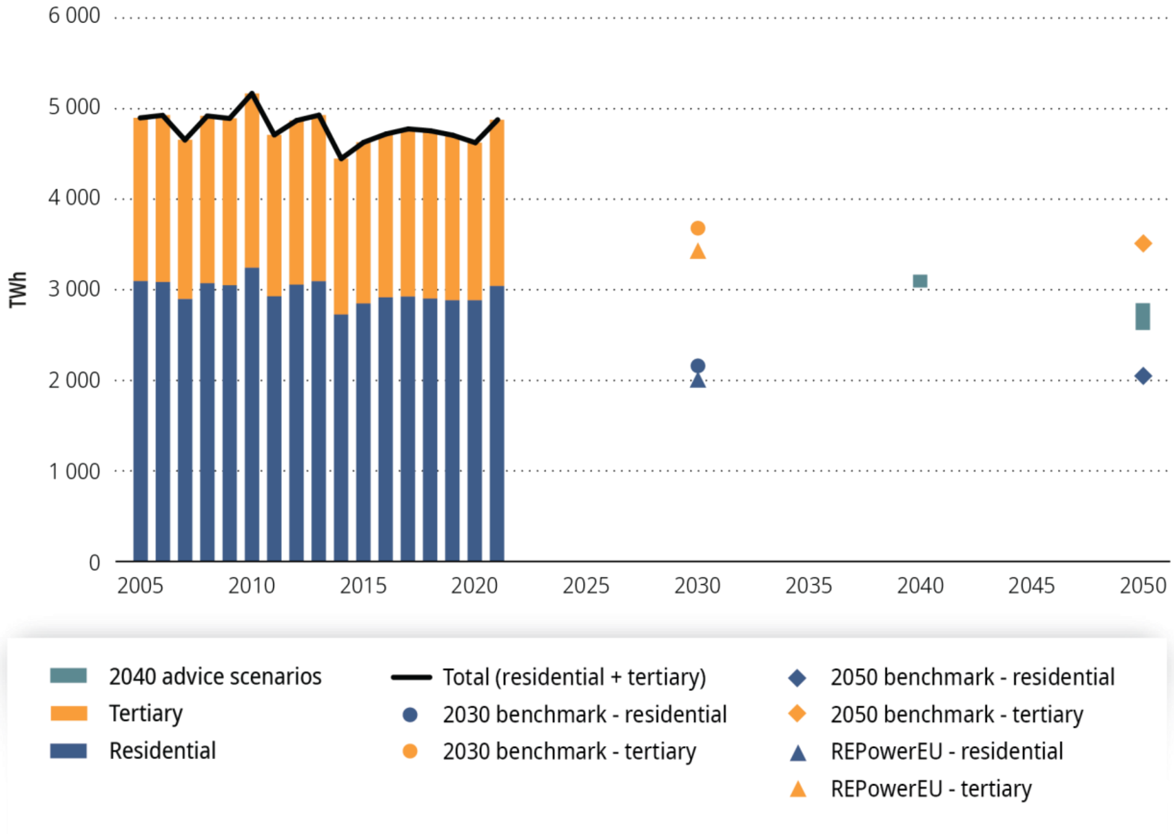
Sources: EU GHG inventory (EEA, 2023f), Fit for 55 MIX scenario (EC, 2021v), Advisory Board 2040 advice scenarios (2023d), In-depth analysis accompanying A Clean Planet for All (EC, 2018e) (Figure 91)

7.3 Outcome 1: reduced energy and material demand

Final energy demand in residential and tertiary buildings does not show a clear declining trend in Figure 48. Significant energy demand reductions are required by 2030 to meet benchmarks consistent with the EU's 2030 climate target underpinned by the REPowerEU plan. The Fit or 55 benchmark would require residential use to fall by 29 % by 2030 compared with the 2021 level, and by 18 % in the tertiary sector. Greater reductions (– 34 % and – 23 % respectively) are envisaged in the REPowerEU scenario. The reduction level consistent with the revised EED lies somewhere between these two levels (EC, 2022a; EU, 2023a) ([3]).

([3]) According to the REPowerEU staff working document (European Commission, 2022a), the Fit for 55 proposals are consistent with reducing final energy consumption (from all sectors) by 9 % in 2030 compared with a reference scenario. The European Commission REPowerEU plan would increase this to 13 %. The revised EED sets a target of 11.7 % compared with the projections of the EU reference scenario, but does not specify the contribution of the residential and service sectors.

Figure 48 Indicator B2 – final energy consumption in the residential and tertiary sectors



Notes: Tertiary sector final energy consumption includes energy from commercial, public, and agricultural buildings. 2030 benchmark and REPowerEU figures refer to energy consumption consistent with the Fit for 55 and REPowerEU scenarios. 2050 benchmark based on the MIX scenario from the Climate Target Plan. All sources include ambient heat harnessed by heat pumps.

Sources: Eurostat energy balances (2023b), REPowerEU staff working document (EC, 2022p) (Table 10), Climate Target Plan (EC, 2020s).

Despite the need to reduce buildings' energy demand, most EU Member States are not on track to meet their energy use targets for 2030 as set in their respective long-term renovation strategies (EC, 2023ba). Regarding the **drivers of energy use by residential and tertiary buildings**, a number of studies suggest that the stability of overall consumption over the past 20 years is in fact due to a variety of countervailing factors, with increased demand related to rising incomes and activity, broadly cancelled out by efficiency improvements driven by energy retrofits, and efficient appliances and new buildings. In the residential sector, Tsemekidi Tzeiranaki et al. (2019) find that energy consumption up to 2016 declined slightly in spite of rising population and incomes, smaller household sizes and increased floor area per capita, aided in part by climatic conditions (fewer heating degree days). They also find that energy efficiency in the residential sector improved, even after adjusting for climatic and economic effects. However, the approximate balance between increased demand and improved efficiency appears to have broken down in more recent years. Reductions in energy consumption have slowed since 2016 (particularly in the residential sector) and most recently appear to have reversed, with energy consumption increasing sharply in 2021. Final energy consumption for heating has fallen steadily since 2005, with the reduction reaching 16 % by 2019 (Odyssee-Mure project, 2023). After controlling for climate effects, this reduction falls to 8 %, suggesting that around half of it is due to a warming climate ([4]). The reduction in energy consumption for heating has far outweighed the increased consumption for cooling in absolute terms (Odyssee-Mure project, 2023). While cooling represents a modest fraction of energy use in buildings today, it is increasing, and studies suggest that it could account for 8–9 % of energy use in residential and non-residential buildings by 2050 (EEA, 2022b).

Regarding material demand, according to the European Commission, the material demand in the EU buildings sector driven by construction activities accounts for about 50 % of all extracted material and is responsible for over 35 % of the EU's total waste generation. GHG emissions from material extraction, manufacturing of construction products, and construction and renovation of buildings are estimated at 5–12 % of total national GHG emissions across the EU. Greater material efficiency could save 80 % of those emissions (EC, 2023c).

Lever: deep retrofits and zero-emission new builds

Improving the energy performance of the existing buildings is a key driver of reduced final energy consumption but its pace is not sufficient to meet the EU climate targets by 2030 and 2050.

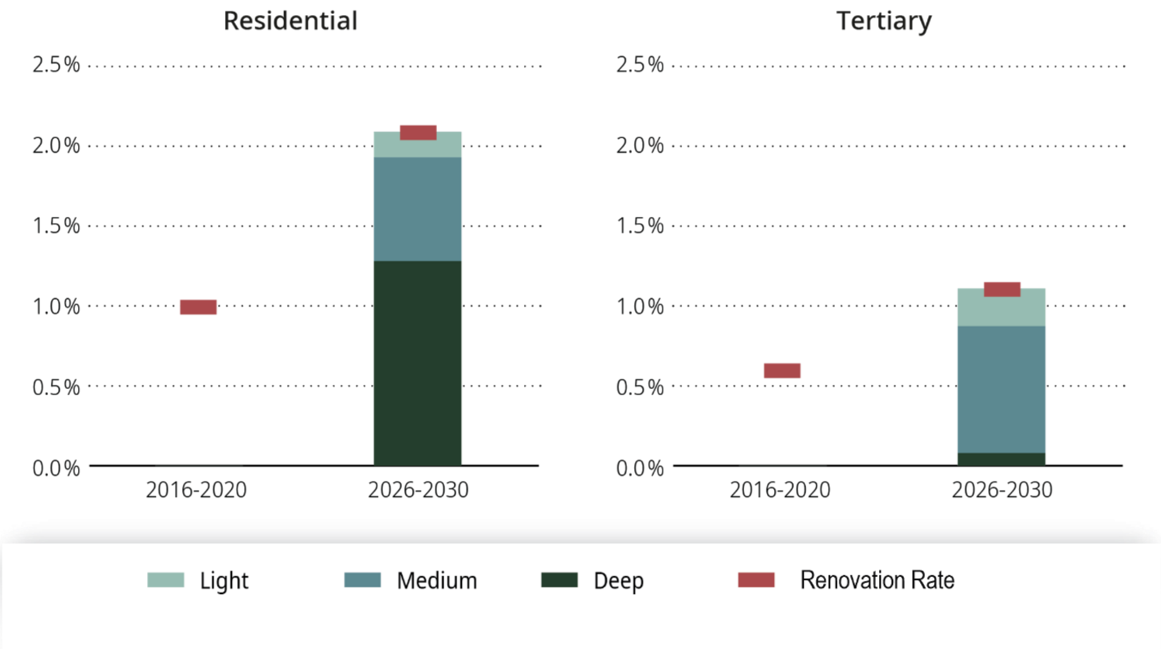
Around three quarters of EU buildings were built before 1990 (EC, 2021i). With the building stock's renewal rate at 1.2 % annually, most of the buildings (85–95 %) standing today in the EU will be there also in 2050. Around 75 % of buildings in the EU are energy inefficient according to current standards (EC, 2021j). Buildings in EPC class A represent a negligible share of the EU building stock (EC, 2021al). Whereas a significant portion of EU buildings are renovated to some extent every year, the depth of the renovation is often very limited. The currently observed retrofits across the EU are dominated by shallow retrofits: incremental changes to energy performance as part of building renovations (EC, 2022f). Only 0.2 % of residential buildings (and 0.3 % of non-residential buildings) are deeply renovated each year. Deep energy retrofits go beyond upgrading of a heating source, and transform the building to zero-emission standard while also improving the occupants' well-being, the dwelling's resilience and the integration of the energy system. To achieve the – 55 % objective, the average renovation rate should be doubled (EC, 2020s) as presented in Figure 49 (indicator B3) below.

The energy retrofits may be part of wider non-energy renovations to address comfort, safety or maintenance issues. Around 15 % of Europeans live in dwellings with leaking roofs or damp walls, floors or foundations, and between 5 % and 39 % live in buildings with rot in the window frames or floors (EEA, 2022a). The available building data is insufficient to indicate the respective energy and non-energy aspects of building renovations, including the depth of energy retrofits and the renovation rate itself (see Section 7.5).

The renovation wave strategy, the EPBD in force and the expected changes under the EPBD recast are intended to encourage deeper energy renovations. The changes included in the revised EPBD (EC, 2021ac) – for instance the introduction of minimum energy performance standards for existing buildings, and tools supporting staged deep renovation, such as a renovation passport towards the zero-emission standard (see Box 4) – go in the right direction in terms of the decarbonisation of buildings. It is too early, however, to comment on the ambition of the EPBD recast or on the delivery of new measures and their overall effectiveness. Its timely implementation will be of the essence, supported by the EU ETS 2. The price signals of the EU ETS and the EU ETS 2, will increase considerably should the progress with the deep retrofits be too slow (see Chapter 10 'Pricing emissions and rewarding removals').

([4]) Controlling for climate effects involves assuming that the number of heating and cooling degree days stands at the long-term average, and adjusting heating and cooling demand accordingly.

Figure 49 Indicator B3 – residential annual renovation rate and depth



Notes: 2016-2020 benchmark data is based on historic data, with 2026-2030 renovation rates and depth for residential and tertiary sectors based on Type 1 renovations (i.e. 'improvement of thermal integrity of buildings through renovation of the building shell') from the MIX scenario of the Climate Target Plan impact assessment. A comparable breakdown of renovation depth is not available for the 2016-2020 benchmark, with only the total renovation rate available.

Sources: Climate Target Plan impact assessment (EC, 2020s) (Figure 53 and Figure 54)

Box 4 From nearly zero-energy to zero-emission buildings

The EPBD recast replaces the **nearly zero-energy** building standard with **zero-emission buildings**, which becomes the new standard for new buildings, the level to be attained by a deep renovation as of 2030 and the vision for the building stock in 2050. It defines a zero-emission building as 'a building with a very high energy performance in line with the energy efficiency first principle, and where the very low amount of energy still required is fully covered by energy from renewable sources at the building or district or community level where technically feasible (notably those generated on-site, from a renewable energy community or from renewable energy or waste heat from a district heating and cooling system)' (EC, 2021ac).

Nearly zero-energy building remains the standard for new buildings until the application of the zero-emission building standard, and becomes the level to be attained by a deep renovation until 2030 (EU, 2010a). It does not require that RES cover the entirety of building energy needs. The specific performance requirement expressed by a numeric indicator of primary energy use in kWh/(m2/y) are defined by the EU Member States.

Ambitious standards underpinned by robust calculation methodologies for zero-emission new builds are urgently needed.

From 2021 all new buildings should be nearly zero-energy under the EPBD in force. The nearly zero-energy buildings requirement has been a strong efficiency standard at the EU level, but there is no uniform approach to its implementation across the EU Member States (D'Agostino et al., 2021a; Tagliapietra et al., 2019) ([5]). The standard is a cost-optimum-driven benchmark level of energy performance (kWh/m²/y) per building type depending on the climatic zone as established by the European Commission (EC, 2016a). A recent assessment of national implementation shows that levels applied in practice are generally lower than those set out by the European Commission, because, among other reasons, different Member States apply different methods to calculate energy flow (D'Agostino et al., 2021a). Moreover, performance requirements of new buildings do not reflect the best available techniques, new materials, behavioural aspects of energy consumption and an integrated approach to building construction (D'Agostino et al., 2021a; Economidou et al., 2020; IPCC, 2022b). The European Commission's proposal for a revised EPBD (EC, 2021ac) requires all new buildings to be zero-emission as of 2030 (see Box 4). The actual **ambition of the revised standards** for new buildings will depend on thresholds of total annual primary energy use and the corresponding calculation methodologies yet to be set out. Energy demand variations due to occupants' behaviour can be significant, so energy performance measurement is more accurate if based on actual consumption, that is, real-world behaviour and building performance rather than a theoretical value, especially when the operation phase is the critical contributor to the total carbon emissions (Zhang and Asutosh, 2023). Advanced digital building management systems offer such dynamic measurements and help bridge the gap between design goals and actual building energy performance (IPCC, 2022b).

The EU needs better long-term planning of its building stock decarbonisation.

The need for better building data and control through digital tools stems also from the findings on the **long-term renovation strategies** for building stock decarbonisation by 2050 required under the EPBD. Such long-term roadmaps, if properly developed, can address the need for careful planning of building renovations (see for example Re Cecconi et al., 2022; Salvia et al., 2021). However, according to the European Commission, the long-term renovation strategies are not robust enough, so 'there is a lack of a clear pathway to deliver on climate neutrality [and] lack of a coherent framework to allow Member States to develop and plan their building decarbonisation' (EC, 2021j). The level of ambition of the strategies is not always in line with the 2050 decarbonisation goals (EC, 2023ba). To improve the long-term strategic planning for building stock decarbonisation under the EPBD, the EU can rely on more harmonised reporting, better planning, and better building data and control through digital tools (Pasichnyi et al., 2019; Salvia et al., 2021) as part of the national building renovation plans ([6]) under the EPBD recast. Such improved long-term planning and reporting could boost sufficiency measures, for example through bioclimatic design of buildings and efficient consumption of space (IPCC, 2022b), and integration of multiple benefits of building retrofits including better indoor air quality, disaster prevention and protection against climate-related hazards. It has to be underpinned by capacity building for municipal administrations, funding identification and coordination within multilevel governance as part of EU climate governance delivery mechanisms (Salvia et al., 2021 see also Chapters 14 'Climate governance' and 15 'Labour, skills and capacity building').

Lever: energy and material sufficiency

Reduction of demand for energy services and floor space has multiple benefits beyond emission reduction, but its potential is largely untapped across the EU. The EU should encourage sufficiency both in the pre-use phase (e.g. through urban and spatial planning) and in buildings use (e.g.

([5]) For example, the average non-renewable primary energy demand for a new single-family houses varies from as low as 15 kWh/m2/y) to 95 kWh/m2/y in different Member States, with an EU-level average of 52 kWh/m2/y (EC, 2023ba).

([6]) Article 3 of the EPBD recast changes the term 'long-term renovations strategies' to 'national building renovation plans'.

through digital solutions, sufficiency-led progressive housing taxation, and adequate energy tax rates under the ETD and carbon price under the EU ETS 2.

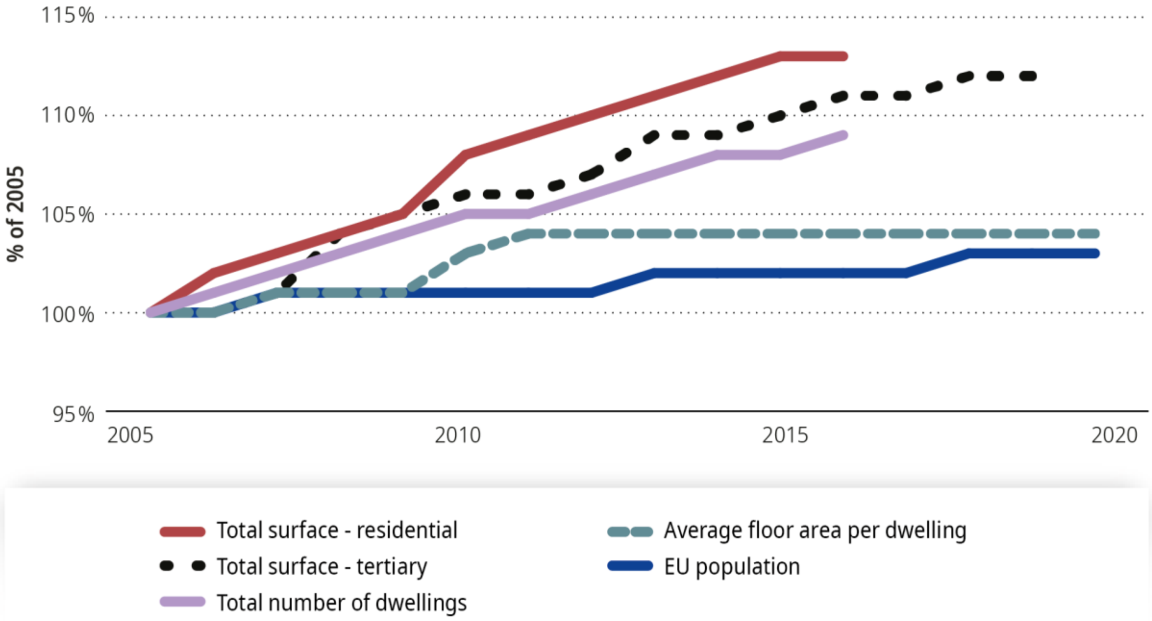
There is a growing scientific consensus regarding the untapped benefits of **reduction of demand for energy services and building materials**, in other words energy and material sufficiency (IPCC, 2022b). Sufficiency-led policies that aim to make better use of existing buildings (Gaspard et al., 2023) can address urban challenges such as energy security, air pollution, ageing populations, social alienation and demographic pressures on (Hook et al., 2023; JRC, 2021c, 2019a; Zannakis et al., 2019). In terms of energy savings, policies focusing on energy sufficiency complement energy efficiency policies (Bertoldi, 2022).

By encouraging cohabitation and higher density per unit of surface area, for example through spatial planning, building codes and taxation, sufficiency measures help to reduce the demand for new accommodation and thus reduce the sector's pressure on resources (see for example Berrill et al., 2021; IRP, 2020; Ivanova and Büchs, 2022). At the city level, compact cities and nature-based solutions, such as for cooling services, can be part of structural sufficiency (Bibri 2020; EEA 2022g) (see also 'Enabling condition: urban and spatial planning' in Section 7.5 below). Building occupants' behaviour driving energy and resource savings can be encouraged by digital tools, such as smart meters, and could be incentivised by innovative policy measures, for instance energy saving feed-in tariffs and personal carbon allowances (Bertoldi, 2022).

Looking at buildings use in the EU, there is no sign of energy and material sufficiency. The trend in building use in recent decades, notably fewer people occupying bigger dwellings, has placed upward pressure on energy consumption and emissions, as Figure 50 demonstrates. Although the total population increase has been modest (+ 3 % since 2005), there have been greater increases in the average floor space per dwelling (which currently stands at 90 m^2) and a reduction in average household size (from 2.4 people in 2010 to 2.3 people today). Between 2020 and 2021 almost all Member States increased their floor area (+ 3 % on average; EC, 2023). The annual number of dwellings for which building permits were granted in the EU increased by a factor of more than 1.3 between 2010 and 2022 (forthcoming).

EU policies do not explicitly focus on energy and material sufficiency in buildings; see for example the renovation wave strategy (EC, 2020b). Moreover, energy price interventions available to EU Member States under the European Commission's State aid guidelines (EC, 2022i), including fossil fuel subsidies (see Section 12.5), and the ETD (see Section 10.5) have been muting financial incentives for sufficiency measures (see for example ESABCC, 2023a). Accordingly, the first round of NECPs have only marginally included building-related sufficiency measures (Zell-Ziegler et al., 2021). Regarding the most recent EU policies, the revised EED and the EPBD recast include provisions that encourage sufficiency, such as consumer information and empowering programmes (EU, 2023e). The upcoming implementation of the EU ETS2 and the ETD revision could also provide sufficiency incentives.

Figure 50 Indicator B4 – population and surface area of homes and businesses



Notes: Data on total number of dwellings and total residential area is only available until 2016, and fragmented.

Sources: European Building Stock Observatory (EC DG Energy, 2023) (total surface – residential, total number of dwellings), Odyssee database (Odyssee-Mure project, 2023) (average floor area per dwelling, total surface – tertiary excluding agriculture), Eurostat (2023) (population, average household size).

Drive sufficiency through housing taxation.

In addition to EU-led measures, national and subnational authorities play a role in driving sufficiency through housing taxation. A recent analysis of the EU Member States' fiscal systems indicates a low level of recurrent property taxation combined with significant tax deductibility for mortgage interest payments, which is often not capped. A significant fraction of the tax income from real estate is from transaction taxes (OECD, 2022). Current taxes favour homeownership for high-income households and indeed increasing home sizes with rising income. They lead to large wealth gains for property owners, and distort households' decisions (JRC, 2019). They adversely affect the efficiency of land and floor space uses and the supply of affordable housing (OECD, 2022). Housing taxation may also be too rigid to encourage residential mobility, for example through transaction taxes and the failure to update property values for recurring taxes, which both constitute tax incentives to stay in large residences even when a family becomes smaller as children or spouses move out (DIW, 2021). Housing taxation also has sizeable distributional impacts (OECD, 2022) and may affect the vulnerability of lower-income households ([7]) (see Chapter 11 'Whole-of-society approach'). Reduced transfer taxes, transfer tax waivers, regular revaluation of taxable values and bonus payments for older couples who sell their houses have been proposed as measures to increase the availability of housing for younger families (Lorek and Spangenberg, 2019; Thomas et al., 2019. The OECD also suggests using housing taxation to provide incentives for energy efficiency upgrades. Both the opportunities and the risks of housing taxation reforms have been recognised in the European Semester process, in which the European Commission

([7]) Lower-income households often live in poorly insulated dwellings and spend a large share of their income on energy and housing. This means they are disproportionately exposed to carbon taxes and stringent building standards (see for example Muellbauer, 2023).

found that 'shifting part of the tax burden from labour to other types of taxes, including environmental and immovable property taxation, while duly taking account of the distributional impact of such a shift, would support the green transition and boost sustainable growth and job creation' (EC, 2023n). Land value taxation ([8]) is also linked to enhanced equity and efficiency of property taxation and may consist of green variants such as split-rate taxes ([9]) that encourage greater urban density and hence boost sufficiency (Muellbauer, 2023; OECD, 2022; Schwerhof et al., 2022). The links between housing taxation, EU climate mitigation efforts and equity need further examination, with a view to guiding Member States' fiscal choices.

Lever: sustainable construction

EU policies do not yet sufficiently leverage resource efficiency and circularity, including extending buildings' lifespans and increasing the intensity of building use, to address embodied carbon and emissions from buildings.

Extending buildings' lifespans and improving building use are among the best ways to lower embodied emissions from buildings (EEA, 2022i; Hertwich, Edgar et al., 2019; IPCC, 2022c, Saenz de Guinoa et al, 2022) and turn parts of the building stock into a temporary carbon sink. In addition, opportunities for material efficiency in the building and construction sector exist at various other levels, with design being one of the key points for intervention. Design is shaped by building codes, which in turn reflect the applicable building policies.

Better building design could address EU buildings' rapidly increasing cooling needs. Use of thermochromic energy-efficient building coating (see for example Butt et al., 2021 and green roofs and facades are among sustainable solutions to this challenge, as they reduce both the heat gains of buildings and the heat island effect (Akbari et al., 2016; EEA, 2021a; IPCC, 2022b). Furthermore, significant life cycle GHG emission reductions are linked to compact, low-rise buildings (IPCC 2022b; Pomponi et al.) and (re)use of recycled and new materials with lower energy and emission intensity than normal ones, for instance replacing concrete with wood and lowering the share of Portland cement thanks to the use of alternative binding materials (IRP, 2020). In the choice of materials, green public procurement, recycled content mandates and virgin material taxation have a role to play (IRP, 2020), and could be facilitated by EU policies (see also Section 5.3).

The EPBD recast is building on an assumption that 'minimizing the whole life-cycle greenhouse gas emissions of buildings requires resource efficiency and circularity', with a new requirement to consider the life cycle global warming potential of new buildings (EC, 2021ac). The life cycle requirement is reinforced by the proposals for the new construction products regulation (EC, 2022x) and for the ecodesign regulation establishing a framework for sustainable products (EC, 2022u). The proposed acts are underpinned by the EU's CEAP 2 (EC, 2020g) and include a mix of policy instruments, mainly regulation and information including standards, labelling and data harmonisation.

The inclusion of embodied GHG emission considerations in the EU building policy framework is a very promising development in terms of 2050 climate neutrality objectives. If the new legal framework proves to be sufficiently robust, leading to timely implementation of standards that have no implementation loopholes and cover key GHG-emitting activities, it can drive the material sufficiency aspect of building

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([8]) Land value taxation is a type of property taxation that falls on the unimproved value of land, as opposed to standard property taxation, which takes the total value of property, including structures built upon it, as the tax base (see for example Barbosa and Skipka, 2019).

([9]) According to the OECD (2022), 'split-rate taxes are a hybrid of pure land value taxes and regular recurrent taxes on immovable property, where both the land and improvements on the land are taxed, but land is typically taxed at a higher rate'.

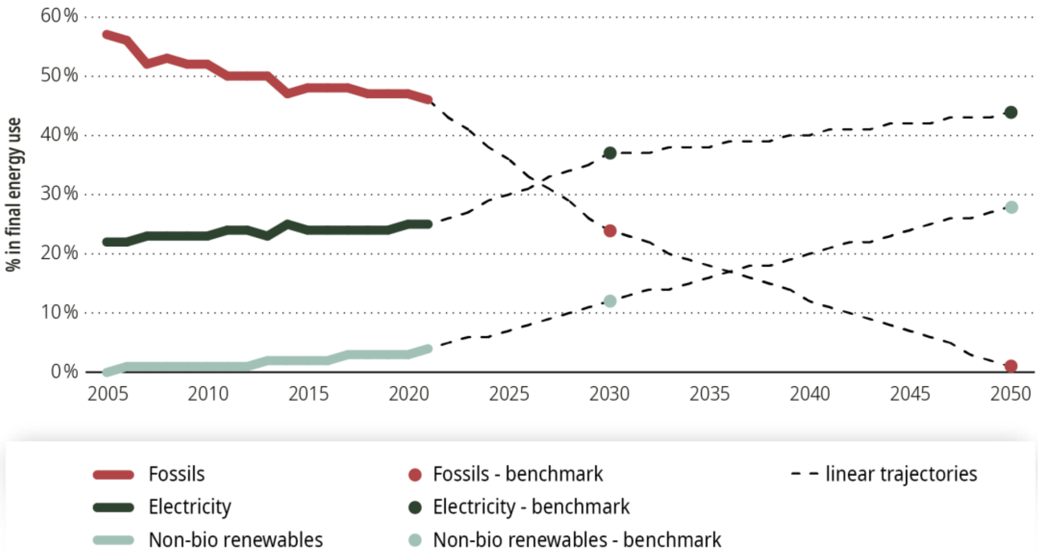
decarbonisation. For this to happen, significant learning and know-how need to be developed along the buildings value chain (see e.g. Michalak and Michałowski, 2022); see also Chapter 15 'Labour, skills and capacity building'.

7.4 Outcome 2: efficient and decarbonised energy supply of buildings

Space heating and water heating represent around 80 % of the energy consumption of residential buildings in the EU (Eurostat, 2023h). Space heating relies mostly on direct use of fossil fuels (EC, 2021j) and is the largest fossil gas consumer in the EU (EC, 2021j). While the share of coal and oil products in residential buildings' consumption has been falling since 2005, no such trend has been observed for fossil gas.

The share of fossil fuels in the energy mix has been declining steadily since 2005, as shown in Figure 51. However, at the current pace (– 0.6 pp per year in 2017–2021), fossil fuels would still account for 42 % of the mix in 2030. The pace of reduction needs to quadruple (to – 2.4 pp per year in 2022–2030) to be consistent with the European Commission scenarios underpinning the 2030 target. Accelerating the phase-out mainly requires a large-scale replacement of fossil fuel boilers by heat pumps, as reflected in the increasing shares of electricity (from + 0.1 pp per year in 2017–2022 to + 1.3 pp per year in 2022–2030) and non-bio renewables, which include ambient heat harnessed by heat pumps (from + 0.3 pp per year in 2017–2021 to + 1 pp per year in 2022–2030). The share of bioenergy has increased from 13 % in 2005 to 17 % in 2012, but has been relatively stable since. Similarly, the share of district heating was relatively stable around 8–9 % in 2005–2021. The shares of both bioenergy and district heating would remain stable until 2050 under the European Commission's decarbonisation scenarios.

Figure 51 Indicator B5a – energy mix in the residential sector



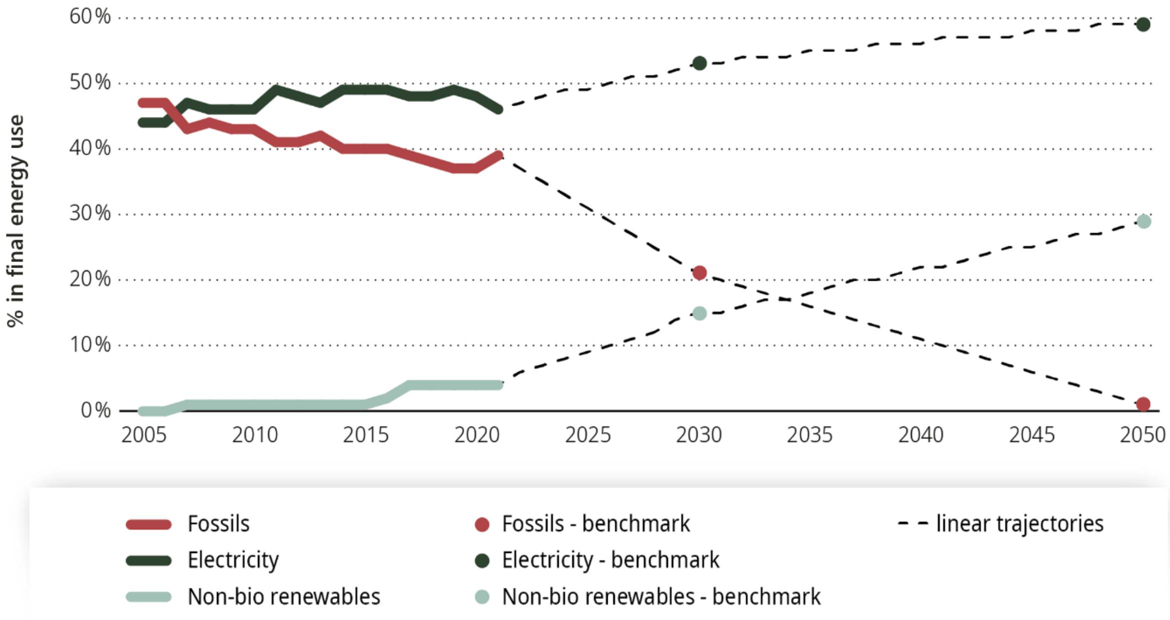
Notes: Benchmark data is based on the MIX scenario from the Climate Target Plan impact assessment. The linear trajectories are shown to increase the readability of the figure, but do not imply that the Advisory Board recommends a linear trajectory towards the benchmarks.

Sources: Eurostat energy balances (2023b), Climate Target Plan impact assessment (EC, 2020s) (Figure 55).

A similar observation can be made about the tertiary sector (see Figure 52, indicator B5b). The share of fossil fuels has declined by 18 % since 2005, although the rate of decline has slowed down in recent years (on average – 0.1 pp per year in 2017–2021). The phase-out needs to accelerate (to, on average, – 2 pp per year in 2022–2030 and – 1 pp per year in 2031–2050) to be consistent with the European Commission scenarios underpinning the EU climate objectives. Under these scenarios, they would mainly be replaced by electricity and non-bio renewables (e.g. ambient heat), whereas the share of bioenergy and district heating would remain relatively stable until 2050.

The RED III (Article 15a) introduced a new indicative national 2030 benchmark of at least 49 % of renewable energy in the buildings sector (EU, 2023f). To achieve the 2030 climate targets, RES roll-out and fossil fuel phase-out need to accelerate.

Figure 52 Indicator B5b – energy mix in the tertiary sector



Notes: Benchmark data is based on the MIX scenario from the Climate Target Plan impact assessment. The linear trajectories are shown to increase the readability of the figure, but do not imply that the Advisory Board recommends a linear trajectory towards the benchmarks.

Sources: Eurostat (2023b), Climate Target Plan impact assessment (EC, 2020s) (Figure 55).

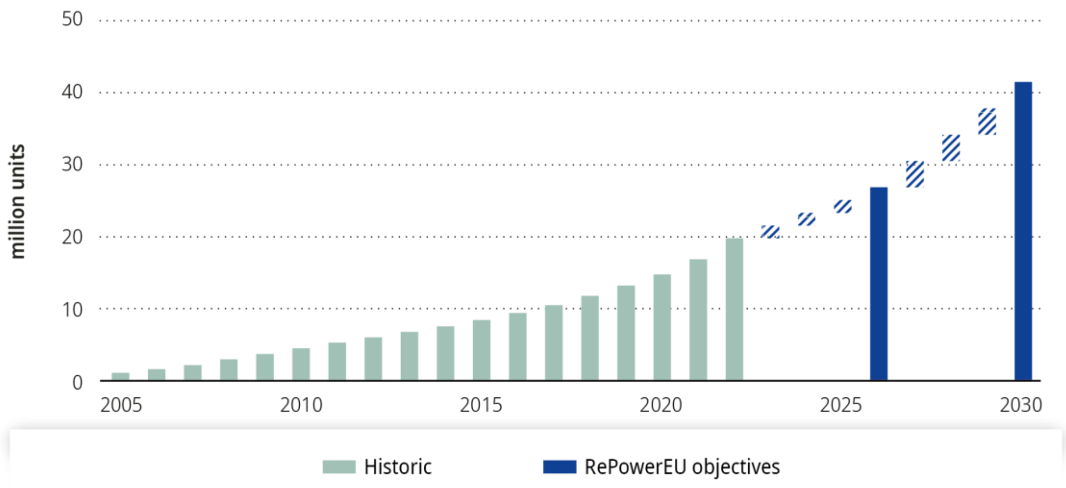
Lever: heat pumps

So far, EU policies have been moderately successful in driving non-fossil fuel switching. Scaling-up of heat pumps and other sustainable heating and cooling sources should accelerate.

Fossil fuels and biomass dominate heating sources in the EU's building stock (EC, 2021j), which is a problem from climate and wider environmental perspectives (see also Chapter 4 'Energy supply' and Chapter 9 'Land use, land use change and forestry'). Net zero transition requires the EU to foster direct electrification of buildings (see Chapter 4 'Energy supply'). This process can be driven by heating source replacement, such as a heat pump taking place of a gas boiler. Heat pumps can be used individually or in conjunction with heat networks and can provide both heating and cooling. This latter function is especially important in the light of experienced and expected rises in temperatures. Heat pumps operate best in highly efficient buildings; hence, their installation should usually be accompanied by insulation and other measures characterising deep building retrofits. Heat pumps can be combined with on-site renewable electricity generation such as solar PV panels and can be backed up by storage solutions (IRENA, 2022b). Their fast and wide-scale roll-out across the EU is a necessity to achieve climate neutrality by 2050. As highlighted by the IPCC, this means 'banning the sale of new fossil fuel-fired boilers, as well as making heat pumps and very efficient appliances standard technologies' (IPCC, 2022b).

The EU heat pump market has grown significantly since 2015, with an acceleration since 2020 (see Figure 53). If the stock of heat pumps continues to grow at its current rate, the EU is on track to achieve the REPowerEU objective of installing 10 million new units by 2026 (EC, 2022m). However, further acceleration will be needed to meet the objective of 41.5 million units installed by 2030.

Figure 53 Indicator B6 - stock of heat pumps (million units) compared with REPowerEU objective



Notes: Dashed bars extrapolating the annual average growth required to meet REPowerEU objectives.

Sources: European Heat Pump Association (EHPA, 2023), REPowerEU Staff Working Document (EC, 2022p).

So far, however, EU policies have been only moderately successful in driving non-fossil fuel switching. This is because, among other reasons, the ETD and EU State aid rules allow subsidies to fossil gas (see Sections 10.5 and 12.3). EU standards and requirements for boilers, driven mainly by the EPBD and the ecodesign directive, have contributed to a decline in heating energy consumption, thanks to, for instance, efficient fossil gas boilers. Moreover, a recent review of scientific contributions regarding EU energy efficiency policies for buildings by Economidou et al. (2020) points out discrepancies in ambition among Member States' efficiency levels for heating and cooling.

A step change in decarbonisation of heating and cooling has been triggered by the European Green Deal and Fit for 55 package, further reinforced by the REPowerEU strategy. The relevant policy landscape is changing drastically following the revisions of heating and cooling product-specific regulations under the ecodesign and energy labelling framework, the EPBD, the RED II, the EED and the ETD, and new measures such as the emergency measure on issuing permits for renewables under Article 122 of the Treaty on the Functioning of the European Union, reforms under the electricity market design proposals (EC, 2023ar), and the proposals for a Net-Zero Industry Act (EC, 2023ao) and for a Critical Raw Materials Act (EC, 2023ac). Heat pumps are listed among net zero technologies under the Net-Zero Industry Act proposal, and an EU heat pump strategy is under preparation. The European Commission warns that 'without a dedicated EU action plan, 22 million old individual heating appliances and several thousand large old fossil-based heating units are at risk of being replaced by fossil boilers' (EC, 2023aj).

Local heating and cooling planning, newly required under the EED for all municipalities with over 45 000 inhabitants, could become a key tool in shifting to sustainable heating and cooling, provided it is properly implemented and expanded to smaller municipalities, with a sense of urgency reflecting the approaching increases in costs of heating with fossil fuel boilers (see Chapter 10 'Pricing emissions and rewarding removals' and Section 14.3 on the importance of multilevel dialogues).

7.5 Enabling conditions

Enabling condition: urban and spatial planning

The EU should systematically promote the integration of climate change considerations into urban and spatial planning, for instance through land use efficiency, the compact city approach and the better use of existing buildings, leading to reduced energy demand and CO_2 emissions, higher RES deployment, climate resilience and societal well-being.

Urban and spatial planning can bring considerable benefits in terms of increased building and land use efficiency leading to, among other things, reduced demand for floor space, faster deployment of renewables and greater capacities of urban and rural settlements to adapt (Devine-Wright, 2015; Kitzing et al., 2021; Nowak et al., 2022; Wiehe et al., 2020). In cities, spatial planning for compact urban form can enable reduced energy demand and changes in service provision, including walkable neighbourhoods and mixed land use, encouraging socio-behavioural change towards active transport (IPCC, 2022k). Urban and spatial planning can also enable electrification and the integration of energy systems (see Chapter 4 'Energy supply') into urban infrastructure. Finally, the IPCC also points out the potential synergies between several sustainable development goals and sustainable land use and urban planning, such as greener spaces, reduced air pollution, improved access to services and opportunities, and demand-side mitigation including shifts to balanced, sustainable, healthy diets (IPCC, 2022l).

Despite the benefits above, many cities in EU Member States are expanding in a dispersed, low-density manner. Such urban sprawl poses difficulties for sustainable land use and the construction of more compact communities, and result in additional transportation needs (Urban Agenda for the EU, 2021).

Rooted deeply in national and subnational decision-making, spatial planning is generally outside the EU's direct field of competence. Nevertheless, it contributes to and has interconnections with several EU policies and initiatives related to climate change, such as the European Green Deal, biodiversity strategy, forest strategy, soil strategy and Nature Restoration Law, strategy on adaptation to climate change, green infrastructure strategy, EU zero pollution action plan, new European Bauhaus initiative, new European mobility framework and the EED. Urban and spatial planning approaches may influence – either enhance or reduce – the potential of the above policies and initiatives to contribute to climate neutrality. Important current initiatives are the mission on climate-neutral and smart cities (EC, 2021; Huovila et al., 2022) with the recent signing of the first climate city contracts, and the European urban initiative (EUI, 2023) which supports urban areas of all sizes with innovative actions, capacity and knowledge building, policy development and communication on sustainable urban development, including greening cities, constructing and renovating in a spirit of circularity and carbon neutrality, adapting and transforming buildings for affordable housing solutions, and regenerating urban spaces.

The orientation for strategic spatial planning is provided by the *Territorial Agenda 2030 – A future for all places*, which was adopted in 2020 as a strategic framework document to support policy responses for societal transformation towards a carbon-/climate-neutral economy. It underlines the importance of balanced territorial development to deal with climate change, to reduce regional vulnerabilities to climate change and to develop capacities for mitigating and adapting to the impacts of climate change (Ministers responsible for Spatial Planning and Territorial Development and/or Territorial Cohesion, 2021). The territorial agenda 2030 promotes actions for stopping net land take by 2050, sustainable land use, open spaces and public green areas, preventing urban sprawl, restoring degraded land and coastal areas, combating deforestation and implementing green infrastructure. It is important to note that the EU territorial agenda 2030 promotes place-based policies for urban regeneration and sustainable urban planning, and considers the application of different geographic approaches, for example using functional urban areas, cross-border areas or urban–rural linkages. A widely recognised trend in the approaches is the creation of functional planning regions that address such flows as commuting patterns, economic relations, river basins, energy networks and others (Nadin and Fernández-Maldonado, 2023). To this end, it is important to assess the potential impact of all placed-based policies and geographic approaches to sectors that contribute to emissions of GHGs, such as transport, energy, agriculture and buildings. Whereas the principle of a place-based approach can support effective climate change mitigation and adaptation plans, functional urban areas may result in additional car-based mobility and land uptake, and should for this reason be treated with caution.

The EU cohesion policy also has a strong sustainable urban development dimension, which is strongly related to climate. For 2021–2027, the urban dimension of cohesion policy has been strengthened, with its policy objectives focusing on a smarter, greener, more connected and more social Europe and a Europe closer to citizens. A minimum of 8 % of the European Regional Development Fund resources in each Member State must be invested in priorities and projects selected by cities themselves and based on their own sustainable urban development strategies. In particular, the focus on a greener Europe refers to a resilient Europe transitioning from a low-carbon towards a net zero-carbon economy, promoting a clean and fair energy transition, green and blue investment, the circular economy, climate change mitigation and adaptation, risk prevention and management, and sustainable urban mobility.

The EU can further support sustainable spatial planning through sharing good practice, building the capacity of local and public authorities, and disseminating guidelines linked to, for example, the European Regional Development Fund and other cohesion policy programmes (ESPON, 2021), and the European Semester process could encourage Member States to improve their spatial planning. There are several EU funding streams addressing sustainable urban planning, such as Urbact IV (which is co-funded by EU cohesion policy funds and aims to enhance the institutional capacity of public authorities (URBACT, 2023) or the European Urban Initiative (EUI, 2023).

Enabling condition: prosumers and positive energy buildings and districts

Net zero transition requires energy system integration allowing buildings to actively participate in the energy system.

The IPCC highlighted the role of market and business models that encourage energy prosumers ([10]), fostering local energy generation and consumption and allowing buildings to actively participate in the energy system. With regard to energy system integration (see Chapter 4 'Energy supply'), new services (e.g. aggregated load management for demand response, peer-to-peer exchanges, energy services companies) will need to complement and to some extent replace the traditional supply of energy services. In this respect energy communities play an increasingly important role (IPCC, 2022b). New services and energy prosumers are encouraged by the falling costs of building-integrated renewables,

([10]) 'Prosumption exists in numerous types and forms: for example, it can be only one household, a group of tenants in a multi-family building or an energy cooperative with participants from the local community. They can produce renewable electricity, heat or both, and some combine this with supporting the grid infrastructure or providing energy storage. Prosumers can apply different ownership structures and business models, which may be run by volunteers or, in the case of larger projects, by paid staff' (EEA, 2022e).

heat pumps and storage technologies, to enable their wide-scale roll-out (D'Agostino et al., 2021; IPCC, 2022c, Ines et al, 2020).

Building-integrated renewable energy infrastructure makes it possible to generate electricity and heat and export them to local networks when they exceed on-site demands. The positive energy balance can be defined at the building or neighbourhood level and could be promoted in parallel with measures aiming to reduce the GHG emissions from building-related uses (EASAC, 2021a). Positive energy districts and compact neighbourhoods could be built on the basis of a 'wider vision of urban sustainability that foresees innovative solutions for street lighting, urban mobility, waste, and public safety' (D'Agostino et al., 2021a; Zakeri et al., 2022). Such integrated planning will further encourage prosumers, energy communities and other citizen-led contribution to climate neutrality.

Positive energy buildings require the roll-out and use of digital building automation and control systems (IPCC, 2022b) as well as smart grids for energy sharing. Notably, distribution networks (low and medium voltage) and business models need to be adjusted to enable the active participation of positive energy buildings. In addition, stationary electric battery storage can unlock unprecedented levels of demand management (see 'Lever: system integration' in Section 4.3).

EU policies, such as the REPowerEU plan and the renovation strategy, recognise the role of prosumers, energy communities and positive energy buildings in the net zero transition. The EU laws enabling individual and collective prosumers and positive energy buildings include the RED III, the EPBD and its recast, the EED and the EU's internal energy market framework. The total number of prosumers in the EU Member States and the EU is not known, because of monitoring gaps (EEA, 2022e). The fragmented available data suggests that number of prosumers is increasing rapidly in some EU Member States. Regarding prosumer-driven demand response, in 2022 only nine EU Member States had given aggregated residential end users access to the wholesale, balancing and ancillary electricity markets (ACER and CEER, 2022). Reasons include, among others, the inadequate national implementation of the EU laws and persisting market participation barriers (Campos et al., 2020; EASAC, 2021a; EC, 2023ag; Magrini et al., 2020; Moura and Brito, 2019; Reis et al., 2013). Given the slow pace of residential demand-side response (ACER and CEER, 2022), the RED III, the European Commission proposals for a Net-Zero Industry Act and reform of the electricity market's design, and the EU action plan on digitalisation of the energy system could accelerate infrastructure development, enabling prosumers, positive energy buildings and system integration. The newly established Energy Communities Repository (EC, 2023x) and the Rural Energy Communities Advisory Hub (EC, 2023bc) are very welcome in this context.

Enabling condition: quality and use of data

Reliable, granular and comparable data on building performance and the multiple benefits of energy efficiency investment are urgently needed to underpin policy measures.

Data availability and comparability are important for decarbonising the building stock, because data is relevant to several aspects of effective policies, including (i) evidence-based policy development and progress assessment, (ii) leveraged private investment in energy retrofits, (iii) energy system integration, new business models and infrastructure, and (iii) behavioural changes thanks to available information (EEFIG, 2023; IPCC, 2022b; Runge-Metzger and Van Ierland, 2019). Why data matters in EU building decarbonisation can be demonstrated by the EPCs, which can inform building owners and induce them to undertake energy renovation. According to Building Performance Institute Europe, 'there is an increasing reliance on EPC data for tracking the progress and the implementation of renovation policies and funding. Yet the uneven quality and reliability of national EPC schemes, coupled with the lack of public trust in the generic list of recommendations may hinder the goal of the EPC to encourage additional investments in energy efficiency' (BPIE, 2023).

The European Commission's assessment of the first long-term renovation strategies and the NECP progress reports concluded that the required data concerning decarbonisation of buildings provided by Member States varies in nature, which makes it difficult to compare the effect of the different national measures and assess their cumulative and quantitative impact. An additional complexity was detected in terms of some key indicators' definitions (EC, 2023, 2022, see also Section 4.3 under 'LeverÆ energy efficieny'). There is a consensus among practitioners, academia and policymakers that EU does not have sufficient and comparable information on the energy performance and other linked parameters of its building stock (EASAC, 2021; EC and EEFIG, 2023; JRC, 2021a).

EPC limitations in terms of reliability of data based on the physical properties of buildings has also been highlighted by the IPCC in the context of energy demand driven by occupancy behaviour (IPCC, 2022b). To further improve data relevant to occupancy and demand patterns, there is a need for a 'social science-based research to investigate how buildings with the same EPC differ statistically in terms of their measured consumption' (Ali et al., 2020). The task of filling this data gap can be helped by smart electricity meters that quantify the load patterns of electric appliances, for example by using disaggregation techniques (EASAC, 2021a).

Similarly, better data is needed to underpin the consideration of non-energy benefits, such as comfort, health and reduced energy poverty, in designing energy efficiency programmes so that they are adjusted to the customers' needs and therefore to stimulate demand for building renovation efforts (EC and EEFIG, 2022). According to the Energy Efficiency Financial Institutions Group convened by the European Commission (2022), identifying multiple benefits, collecting data on them and evaluating them strengthen the connection between energy efficiency investing and impact investing, as well as decision-making by financial institutions. Thus it can make investing in buildings' energy efficiency more attractive to private investors (see 'Enabling condition: private investment' below).

The EU policy measures driving the collection and use of this essential data include the EPBD, the Infrastructure for Spatial Information in Europe directive (EU, 2007), non-legislative initiatives such as the EU Building Stock Observatory and Odyssee-Mure database (ADEME et al., 2023), the renovation wave strategy (EC, 2020h) and the EU action plan on digitalisation of the energy system (EC, 2022k). Regarding spatial planning and urban land use efficiency, it is the EU Copernicus programme that provides an insight complementary to the building-level data (EEA, 2023e; Schiavina et al., 2022)

The EPBD recast strengthens the role of the EU Building Stock Observatory as the EU database for data related to building renovation, EPC and smart readiness indicators. Importantly, a step change in this respect could be driven by the EU action plan on digitalisation of the energy system (EC, 2022k), which recognises the need for seamless data exchanges 'supporting smart energy buildings as a source of renewable energy production and flexibility in the energy system, and making the data from buildings available to define business cases for renovation' (EC, 2022k). It includes putting in place a common European energy data space for improving access to, exchange of and reuse of data. These developments are still at early stage of delivery but have significant potential to contribute to decarbonising the building stock across the EU.

Enabling condition: private investment

EU policies need to better leverage private investment in the energy efficiency of buildings and avoid lock-in risks linked to shallow retrofits.

Decarbonising EU's building stock by 2050 requires the scaling-up of private investment to meet estimated additional investment needs of EUR 90 billion per year (EC, 2020h). Estimates by the JRC indicate that across the EU around EUR 15 billion per year are allocated to energy efficiency in buildings (JRC, 2019a). The energy efficiency investment gap is well documented in academic publications (see e.g.

Bertoldi et al., 2021) and reflected in several EU policy documents (see e.g. EC, 2020f). It points to the great heterogeneity of the buildings sector, which is subject to, among other challenges, split incentives, inadequate information about costs and benefits of energy retrofit investment, loss aversion, complex decision-making processes, long pay-back periods and high transaction costs that hamper private investment (Economidou et al., 2020; IPCC, 2022c, Perez Navarro et al, 2023). For those reasons, technical support is often the key enabler to attract private investment in the energy efficiency of buildings, as it helps to overcome the various organisational and other non-financial obstacles such as the split incentive dilemma and the need for investment aggregation.

Analysis of the recovery and resilience plans submitted by the EU Member States to the European Commission in 2022 shows that 'most of the spending on energy efficient renovations goes to schemes that have the objective to achieve, on average, a medium-depth level renovation, which amounts to at least 30 % primary energy saving' (EC, 2022f). In 2022 a flagship technical support to Member States was launched under the RRF regulation (EU, 2021a), with a focus on (i) renovation along thematic areas of the Renovation Wave, including energy poverty alleviation, public buildings and the wider renovation ecosystem; (ii) the implementation of planning tools, especially long-term renovation strategies and recovery plans; and (iii) the implementation of cohesion policy funding for building renovation.

The rather shallow depth of energy retrofits in the Member States' plans under the RRF appears to echo the technical screening criteria (TSC) for sustainable economic activities set out in the delegated act supplementing the Taxonomy Regulation (EU, 2020). The TSC for renovation of existing buildings require building renovation to comply with the applicable requirements for major renovations under the EPBD or to lead to a reduction of primary energy demand of at least 30 %. Such shallow energy retrofits may not be aligned with the EU's climate neutrality objective and may create dangerous lock-ins (see for example Schütze and Stede, 2021) unless they are part of a staged intervention, for instance under a building renovation passport leading to a deep retrofit while recognising the complexity of such investment (BPIE, 2017; Sesana et al., 2020; Villarejo et al., 2021). Voluntary building renovation passports will be introduced in the EPBD recast.

Regarding the new construction, acquisition and ownership of buildings, the criteria are somewhat more robust, as, for buildings constructed in 2022 and after, they go beyond the current EPBD requirements (EC, 2021b).

Several EU funding schemes aim to bridge the investment gap by supporting the retrofitting of buildings. Such support ranges from research and market uptake to large-scale retrofits as part of the EU cohesion policy. In the 2014–2020 programming period, the cost-effectiveness of the EU cohesion policy spending on energy efficiency in buildings (about EUR 14 billion over the period) was rather low because of inadequate targeting of investments through grants with low additionality, that is, crowding out private investment that would probably have happened anyway. Moreover, the monitoring system in place did not make it possible to measure energy savings triggered by the investment (ECA, 2020a). Both weaknesses – lack of additionality, and inadequate data about impact – perpetuate the challenge of attracting private finance to invest in the energy efficiency of buildings.

To make better use of public funds, some EU funding programmes (e.g. L'Instrument Financier pour l'Environnement (LIFE), Horizon, InvestEU) develop, test and scale up financing schemes and business models such as on-bill financing, one-stop shops and energy performance contracting, in line with the IPCC findings (IPCC, 2022c, Sequeira, & Gouveia, 2022, Pardalis et al, 2022). They also provide financial guarantees and project development assistance to energy efficiency investment at building portfolio levels ([11]). These are promising efforts to leverage private investment through public funds, but they should go hand in hand with fiscal policy within the EU Member States, supported by the upcoming revision of the ETD (EC, 2021y) and the State aid guidelines to discourage further use of fossil gas as a heating source for buildings (see also Sections 10.5 and 12.3).

([11]) For instance, the European Local Energy Assistance programme created under Horizon 2020 and implemented by the EIB leverages private investment in the energy efficiency of buildings (EIB, 2023a). The EIB is also crowding in private finance to sustainable infrastructure for buildings by providing financial guarantees under the InvestEU programme. The overall InvestEU Fund budget guarantee of EUR 26.2 billion is expected to trigger EUR 372 billion of public and private investment in all sectors between 2021 and 2027 (EU, 2023h).

7.6 Summary tables

Table 10 Progress summary - buildings

Indicator	Reference period	Historical progress	Required up to 2030	Required in 2031–2050
B1: GHG emissions	2005–2022	– 11 Mt CO_2e/yr	– 29 Mt CO_2e/yr	– 11 Mt CO_2e/yr
B2: final energy use				
B2a: residential	2017–2021	+ 29 TWh/yr	– 98 to – 113 TWh/yr	– 35 to – 42 TWh/yr
B2b: tertiary	2017–2021	+ 23 TWh/yr	– 36 to – 47 TWh/yr	– 15 to – 21 TWh/yr
B3: Type 1 renovation rate				
B3a: residential buildings	2016-2020	+ 1 %/yr	+ 2.1 %/yr	*No benchmark*
B3b: tertiary buildings	2016-2020	+ 0.6 %/yr	+ 1.1 %/yr	*No benchmark*
B4: built surface				
B4a: residential surface area	2012–2016	+ 128 km^2/yr	*No benchmark*	*No benchmark*
B4b: tertiary surface area	2015–2019	+ 23 km^2/yr	*No benchmark*	*No benchmark*
B5: fuel mix				
T5a: % of fossils in residential final energy consumption	2017–2021	– 0.6 pp/yr	– 2.4 pp/yr	– 1.1 pp/yr
T5b: % of fossils in tertiary final energy consumption	2017–2021	– 0.1 pp/yr	– 1.9 pp/yr	– 1.0 pp/yr
B6: heat pumps (total stock)	2018–2022	+ 2 million/yr	+ 2.7 million/yr	*No benchmark*

Legend

On track	The required change ([a]) is ≤ 1.
Almost on track	The required change ([a]) is between 1 and 1.5.
Somewhat off track	The required change ([a]) is between 1.5 and 2.
Considerably off track	The required change ([a]) is ≥ 2.
Wrong direction	The required change ([a]) is < 0.

([a]) See Section 2.2 for more details on how the required change is calculated.

Table 11 Policy consistency summary - buildings

Policy inconsistencies	– Subsidies to fossil gas persist as they are allowed under the Energy Taxation Directive and EU state aid rules
Policy gaps	– In terms of heating and cooling decarbonisation, lack of system integration and insufficiently robust EU standards have led to incremental energy efficiency improvements and lock-in effects. – The EPBD recast aiming to tackle buildings' embodied carbon and energy, which could encourage better use of the existing buildings rather than new construction, has not yet been adopted. – EU policies have not sufficiently facilitated collection and sharing of reliable, granular, comparable and interoperable information on the energy performance, energy efficiency investment and multiple benefits of efficient building stock, such as indoor air quality.
Ambition gaps	– The revised EED and the EPBD before recast do not explicitly aim to leverage sufficiency. – The EU does not prominently guide urban and spatial planning and taxation towards energy and material sufficiency. – The EPC schemes are of uneven quality and have limitations in terms of reliability, as they are based on data derived from the physical properties of buildings rather than energy demand driven by occupancy behaviour.
Implementation gaps	– EU policies so far have not overcome barriers to wide-scale and deep energy retrofits of buildings. – The quality and ambition of the EU's long-term renovation strategies are insufficient to guide the required building renovation towards the 2050 climate neutrality objective.

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