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Accelerating the Decarbonization of China's Residential Building Sector: Policy insights from the EU

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1. Introduction

The European Union (EU) has set ambitious climate goals, striving to achieve climate neutrality by 2050 and reduce greenhouse gas (GHG) emissions by at least 55% compared to 1990 levels by 2030.[1] Direct CO_2 emissions from energy use in residential buildings reached 306 $MtCO_2$ in 2021.[2] With a share of 34% of energy-related CO_2 emissions in 2022, the buildings sector is a major contributor to GHG emissions in the EU.[3,4] Thus, improving the energy efficiency of residential buildings has emerged as a critical lever for achieving its climate target. The EU and its Member States have long been at the forefront of this endeavour, developing a multifaceted policy package that combines a set of overarching strategies and market policies, building energy codes, financial incentives, information instruments. While these policies have faced implementation challenges and varied success across regions, they provide a wealth of experience for other nations aiming to refine their own building decarbonization strategies.

China, which has committed to peaking CO_2 emissions before 2030 and achieving carbon neutrality by 2060, faces a similarly urgent need to improve energy efficiency in its residential building sector. With an expansive building stock exceeding 53 billion m^2 in 2022—35.1 billion m^2 in urban areas and 21.9 billion m^2 in rural areas—residential buildings accounted for more than 1.3 billion tonnes of CO_2 emissions, representing nearly 60% of total building-related emissions, including both direct and indirect sources.[5] Given this scale, energy efficiency in China's residential sector is critical for meeting its climate goals. China has already embarked on ambitious building efficiency policies through initiatives such as the clean heating and increasingly stringent urban energy performance standards.

This report provides an overview of the decarbonization efforts of residential buildings in the EU, outlining its overarching policy framework and analysing key policy instruments in detail. By presenting the latest EU policies, identifying critical success factors of specific measures, and assessing the current residential building policies in China, this report aims to offer valuable insights to accelerate the decarbonization of China's residential building sector. Additionally, it seeks to contribute to global discussions on effective policies for reducing emissions in the residential building sector.

[1] European Commission (2023a)
[2] BPIE (2022)
[3] EEA (2024)
[4] In addition to direct CO_2 emissions, this also includes indirect emissions from electricity and district heat, as well as construction. It also includes non-residential buildings.
[5] THUBERC (2024)

2. Decarbonising Residential Buildings in the EU

2.1 Energy Landscape of the EU's Residential Building Sector

The residential sector is a critical component of the EU's energy landscape, accounting for approximately 25.8% of the EU's final energy consumption in 2022. Space heating remains the dominant energy use in households, representing 63.5% of total residential energy consumption. The sector's energy mix in 2022 was primarily composed of natural gas (30.9%), electricity (25.1%), renewables and waste (22.6%), and oil and petroleum products (10.9%).[6] This heavy reliance on fossil fuels underscores the pressing need for decarbonization measures.

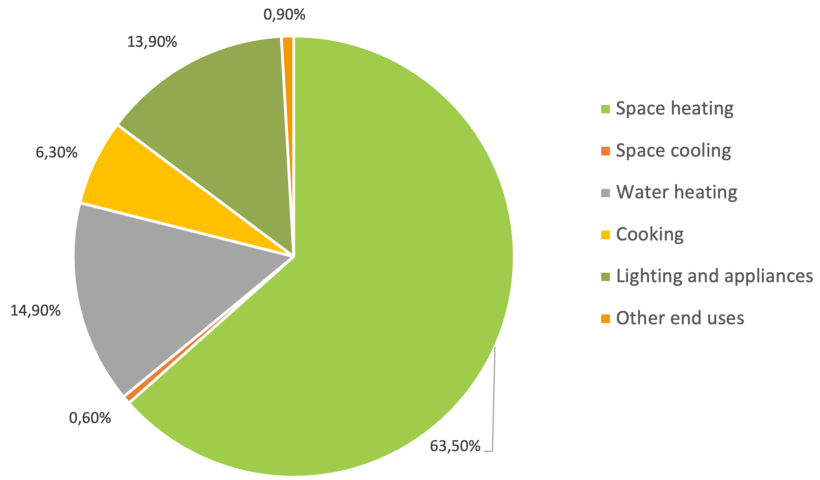

Figure 1 Energy consumption in EU households in 2022

Source: Eurostat[7]

A significant challenge in the EU's building sector is the age of its stock, with many buildings built before the introduction of modern energy efficiency requirements. As a result, a large proportion of existing buildings are highly inefficient and require extensive renovation.[8] It is estimated that between 75% and 95% of today's buildings will still be in use by 2050, meaning that achieving the EU's climate targets will necessitate widespread energy retrofitting.[9] However, the pace of renovation remains slow, with the annual renovation rate of residential buildings remaining below 1%.[10] Moreover, many completed renovations achieve only limited energy savings.

2.2 Strategies for Residential Building Decarbonization in the EU

To achieve a zero-emission building stock in the EU by 2050, deep energy renovation emerges as the primary strategy. If all EU residential buildings were renovated to achieve at least 20% energy savings in the building envelope, an estimated 777 TWh of energy could be saved.[11]

Another key pillar of residential building decarbonization in the EU is the electrification of heating, which is closely tied to the rapid expansion of renewable energy sources. In 2023, a total of 3.02 million heat pumps were sold, increasing the cumulative installations to nearly 24 million across Europe.[12] To align

[6] European Union (2024, updated 2025)
[7] Eurostat (2024) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households
[8] EESC (2022)
[9] BPIE (2017)
[10] Filippidou et al. (2023)
[11] Fabbri et al. (2023)
[12] European Commission (2019)

with EU's 2050 climate targets, the European Heat Pump Association estimates that at least 60 million heat pumps need to be operational by 2030.[13] In central and northern parts of the EU, district heating is another important source of heating that enables the indirect use of renewable energy sources and waste heat.

By integrating large-scale renovations with heating electrification and renewable energy deployment, the EU is pursuing a comprehensive strategy to achieve deep decarbonization in the residential building sector. However, challenges remain, including the need to scale up renovation rates, ensure affordability, and address disparities in policy implementation across Member States.

2.3 Policies for Residential Building Decarbonization in the EU and Member States

This chapter provides an overview of the key building decarbonization policies in the EU and Member States. It also highlights examples of good practice policy initiatives from Member States, providing insights into national efforts to accelerate the decarbonization of buildings.

The European Green Deal is the European Union's (EU) overarching strategy to achieve climate neutrality by 2050. As part of this ambitious strategy, the European Commission (EC) has adopted the 'Fit for 55' package, which aims to reduce GHG emissions by 55% by 2030 compared to 1990 levels. This package includes a wide range of revised legislative proposals designed to transform multiple sectors of the economy.[14] Recognizing the key role of buildings in achieving climate change targets, the 'Fit for 55' package includes several key legislative measures specifically targeted at the building sector, which are outlined below. These measures aim to improve energy efficiency, integrate renewable energy sources, and promote the deep energy renovation of existing buildings to ensure that the sector makes an effective contribution to climate neutrality.

2.3.1 Overarching policies for residential building decarbonization

Overarching target

The **Energy Performance of Buildings Directive (EPBD)**, recast as Directive (EU) 2024/1275, is a cornerstone of the European Union's (EU) regulatory framework for decarbonizing buildings. To strengthen the implementation of energy renovation, the EPBD now mandates all EU Member States to establish long-term building renovation plans to transform their national building stock into zero emission buildings by 2050. These strategies must include clear roadmaps with specific measures, measurable progress indicators, and indicative milestones for 2030, 2040, and 2050. These plans will be more closely aligned with national energy and climate plans, ensuring better integration of building renovation strategies with broader climate objectives.[15] By focusing on cost-effective, deep energy renovations, the EPBD aims to significantly improve the energy performance of buildings across the EU. This 2024 revision of the EPBD, adopted as part of the 'Fit for 55' package, introduces further, more ambitious targets and provisions to accelerate the decarbonization of the building sector. Key updates include:

- **Zero emission standards for new buildings**: All newly constructed buildings must be zero emission by 2030, with publicly owned or occupied buildings meeting this standard by 2028.
- **Energy demand reduction targets for existing buildings**: Requirement to reduce primary energy consumption of residential buildings by 16% by 2030, with a further reduction to 20-22% by 2035.

[13] European Heat Pump Association and European Climate Foundation (2023)

[14] Meanwhile, most of the legislative proposals have been adopted.

[15] European Union (2024)

- **Renovation of the worst performing non-residential buildings**: The Directive requires the renovation of 16% of the worst performing non-residential buildings by 2030, rising to 26% by 2033, based on minimum energy performance standards.

These new provisions add to other previous or new ones of the EPBD, such as minimum energy performance requirements for new buildings and in case of major renovation (cf. section 2.3.4), Energy Performance Certificates (section 2.3.4), and the installation of One-Stop-Shops (section 2.3.6).

Additionally, the **Effort Sharing Regulation (ESR)** sets binding annual greenhouse gas emission reduction targets for Member States in sectors not covered by the EU Emissions Trading System 1 (ETS1) or the Regulation on Land Use, Land-Use Change, and Forestry (LULUCF), including the building sector. The ESR aims to reduce emissions from these sectors by 40% by 2030 compared to 2005 levels, but is not specified by sector.[16]

2.3.2 Pricing mechanism

A core pricing instrument in the EU's decarbonization strategy is the **Emissions Trading System 1 (EU ETS1),** which has been in operation since 2005 and currently covers around **40% of the EU's total GHG emissions** from electricity, large heat generators, and industrial emissions.[17] Within the building sector, the existing EU ETS covers only 30% of emissions, mainly from electricity and district heat.[18] To address this gap, in 2023, the 'Fit for 55' package introduced a new emissions trading system (**EU ETS2**) covering fuel combustion in buildings, road transport, and other additional sectors. The ETS2 will **become operational in 2027** and will significantly expand carbon pricing in the EU.[19]

Key design features of the ETS2

- **Coverage:** CO_2 emissions from fuel combustion in buildings, road transport and additional sectors
- **Point of regulation:** upstream, at the level of fuel suppliers, i.e. distributors of coal, natural gas, heating oil, gasoline, and diesel
- **Expectation:** firms pass on most or all of their compliance costs to consumers by increasing fuel prices of households and small businesses
- **Amount of allowances and cap reduction trajectory:** in line with the buildings and road transport sectoral target of 42% emissions reduction by 2030 compared to 2005; target of 100% emissions reduction by ca. 2042
- **Allowance allocation:** Auctioning; price stability measures envisaged by releasing additional allowances from the Market Stability Reserve
- **Auctioning revenues:** distributed between Member States and the Social Climate Fonds

Source: based on Eden et al. (2023)

At the national level, several EU Member States have already implemented carbon pricing for fuels used in buildings,[20] with Sweden serving as a leading example.

Carbon Tax in Sweden

Introduced in 1991, Sweden's carbon tax has been progressively increased over the years, reaching **EUR 123 per tonne of CO_2** equivalent in 2023, making it one of the highest carbon taxes globally.

[16] European Commission (n.d. a)
[17] Thomas et al. (2021)
[18] European Commission (2020)
[19] European Commission (n.d. b)
[20] Sweden, Finland, France, Ireland, Germany, Denmark, Portugal, Luxembourg, Slovenia, and Austria (RAP toolbox)

Sweden's carbon tax was introduced as part of **a broader tax reform**, which included[21]:

- **Reductions in existing energy taxes,** previously applied uniformly across all energy sources, irrespective of carbon content
- **Cuts to income tax and other fiscal adjustments**, designed to minimize the overall tax burden on businesses and mitigate distortions caused by pre-existing taxation structures.

The carbon tax applies to **all fossil fuels based on their carbon content**, creating a direct economic incentive for emissions reduction. Revenue from the tax flows into **Sweden's general public budget** rather than being earmarked for specific climate initiatives. However, the general budget is **frequently used for climate-related measures**, such as mitigating **social distributional effects of the tax, funding renewable energy investments, and supporting energy efficiency programs.** [22] Moreover, a critical factor underpinning the high level of public acceptance for the tax is the practice of **announcing rate increases well in advance**, giving households and businesses sufficient time to adjust and plan accordingly.

Sweden's experience highlights how carbon pricing can drive structural shifts in energy consumption. In the heating sector, the carbon tax played a pivotal role in reducing fossil fuel reliance, leading to an **85% decline in fossil fuel use** between 1990 and 2018.[23]

Other pricing mechanisms affecting fuel use in buildings are based on **energy pricing**.

- **Energy taxes and levies** on energy carriers. From 2020, taxes and levies on electricity exceed those on fossil gas in most Member States.[24] In 2021, the EC **proposed a reform of the Energy Taxation Directive** to ensure that **electricity will always be the least taxed energy carrier**. This reflects the expectation that its environmental damage costs will soon be lower than those of fossil fuels and biomass.[25] This proposal has not yet been adopted.
- **Metering-based billing of heating costs:** Since 2012, the Energy Efficiency Directive (EED) has required metering-based billing for heating costs, ensuring that consumers are charged according to their actual energy consumption. This requirement builds on the earlier provisions of the Energy Services Directive (ESD) from 2006, which already emphasized the importance of accurate and transparent billing to promote energy efficiency. By mandating individual metering where technically feasible and cost-effective, these provisions aim to encourage energy-saving behaviour and improve cost allocation in multi-occupancy buildings.
- **Dynamic electricity pricing:** The growing share of variable renewable energies (photovoltaics and wind energy) and of electrification are expected to significantly influence electricity demand patterns and the need to provide flexibility in these, amplifying the importance of dynamic pricing mechanisms. The Electricity Directive (EU) 2019/944 mandates that smart meters must be equipped with functionalities to support dynamic pricing mechanisms. To strengthen consumer access to flexible pricing, the Electricity Market Directive (EU) 2024/1711 introduces amendments to Article 11 of Directive 2019/944. Member States must ensure that their national regulatory frameworks enable suppliers to offer both fixed-term, fixed-price electricity supply contracts and dynamic electricity price contracts. Furthermore, final customers with smart meters must be able to request a dynamic electricity price contract, while all final customers must have access to a fixed-term, fixed-price electricity contract with a duration of at least one year from at least one supplier, as well as from every supplier serving more than 200,000 final

[21] Akerfeldt and Hammer (2015)
[22] Government Office of Sweden (n.d.)
[23] Akerfeldt and Waluszewski (2018)
[24] Rosenow et al. (2022)
[25] European Commission (2021)

customers. Recognizing the need to improve tariff structures, the European Commission unveiled the Affordable Energy Action Plan in February 2025. This plan aims to introduce new electricity tariffs that allow users to benefit from lower electricity prices at different times, with implementation targeted for the second quarter of 2025. This would enable consumers, especially those operating heat pumps, to optimize their energy use and take advantage of lower rates during off-peak periods. Across EU Member States, the adoption of dynamic electricity pricing varies significantly. Scandinavian countries, including Norway, Sweden, Finland, and Denmark, are leading the way, benefiting from high smart meter penetration and widespread use of EVs and heat pumps. In these markets, many suppliers offer dynamic tariffs and smart technologies to optimize electricity consumption.[26] Further south, the Netherlands and Belgium (Flanders) are increasingly integrating dynamic pricing, while Germany is preparing for a major expansion. Under the Law on the Restart of the Digitalization of the Energy Transition, dynamic pricing must be offered from 2025 where smart meters are available, alongside measures to accelerate smart meter rollout. Additionally, time-variable grid fees will be introduced for owners of heat pumps and battery electric vehicles (BEVs) subject to regulation under §14a EnWG, providing incentives for grid-friendly consumption. Traditional ToU tariffs with day/night differentiation are still the most common in other EU markets with a high share of smart meters, like Italy, Spain and France.[27]

2.3.3 Overarching Funds

- **The Social Climate Fund (SCF) at the EU level**

As part of the 'Fit for 55' policy package, the EC is introducing the Social Climate Fund (SCF), established by the Social Climate Fund Regulation. The SCF aims **to mitigate the socio-economic impacts of carbon pricing on vulnerable households**, **transport users, and micro-enterprises** that may experience disproportionate cost increases due to the extension of the **ETS2** and the rising cost of fossil fuels.[28]

The SCF will provide support through two main mechanisms:

- **Structural measures and long-term investments** focused on reducing CO_2 emissions, particularly in the building and transport sectors.
- **Temporary direct income support** to alleviate short-term affordability challenges for vulnerable groups.

To ensure effective implementation, each Member State is required to develop a **Social Climate Plan (SCP)** by 30 June 2025. These plans must present a coherent set of measures and investments tailored to mitigate the socio-economic impact of the ETS 2. The SCPs should include both national and, where applicable, local and regional measures and investments.

Up to €65 billion will be allocated to the SCF over the period 2026-2032. In addition, Member States will be required to co-finance at least 25% of the costs of the measures and investments included in their National Social Climate Plans, e.g., by using part of the revenues from auctioning their allowances under the ETS2. In total, the SCF will mobilize around €86.7 billion.[29] Among others, key priority areas under the SCF include **building renovation and the decarbonization of heating and cooling systems**, with a focus on integrating renewable energy sources and energy storage solutions.[30]

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[26] RAP (n.d.)

[27] RAP (n.d.)

[28] European Union (2023)

[29] Carbon Market Watch (2024)

[30] European Commission (n.d. c)

- **Energy Efficiency Funds of Member States**

Overarching energy efficiency funds have been instrumental in promoting energy efficiency across sectors and have been operational in more than ten EU Member States since the 1990s. They are explicitly allowed and encouraged in the Energy Efficiency Directive (EED; first adopted in 2012, current version Directive (EU) 2023/1791). These funds **support long-term energy efficiency initiatives and are financed through multiple sources**, including **general public budgets, revenues from the EU-ETS, and other dedicated funding mechanisms**.[31] By securing sustainable funding sources, these programs ensure consistent investments in energy efficiency improvements, including the building sector.

2.3.4 Building energy regulations and building information disclosure

The EPBD, first introduced in 2002, mandates all EU Member States to **set cost-optimal Minimum Energy Performance Requirements (MEPRs) for new buildings and major renovations**[32] **of large existing buildings**. Over the years, the Directive has been progressively strengthened to align with the EU's energy and climate targets.

The latest recast of the EPBD, which entered into force in 2024, requires all new buildings to be **Zero Emission Buildings (ZEBs) from 1 January 2030**. A Zero Emission Building is defined as **one with very high energy performance, where the remaining low energy demand is fully covered by renewable sources,** without on-site carbon emissions from fossil fuels. The directive also introduces a lifecycle Global Warming Potential (GWP) calculation to assess a building's total carbon impact over its lifetime.[33]

To improve transparency and drive energy efficiency upgrades, the EPBD also introduced **Energy Performance Certificates (EPCs)** in 2002. These labels display information of a **building's energy performance and provide recommendations for improvements to it**. EPCs are **mandatory for new buildings and for existing buildings** in specific situations, such as **major renovations, sales, new rentals, or rental contract renewals**, ensuring that potential buyers and tenants are well-informed.

A significant update in the 2024 EPBD revision is the introduction of a **harmonized EU-wide EPC rating scale,** ranging from '**A' to 'G',** to improve comparability across Member States. Class 'G' represents the very worst-performing ca. 15% of buildings in each country, while Class 'A' corresponds to Zero Emission Buildings. This standardization enhances transparency and helps track progress toward the EU's long-term decarbonization goals.[34]

Below are three examples of MEPRs implementation at the Member State level.

Germany

The Buildings Energy Act (Gebäudeenergiegesetz, GEG), **enacted in 2020**, serves as Germany's comprehensive legislation governing energy performance requirements for new constructions, existing building stock, and the utilization of renewable energy for heating and cooling in buildings. This act consolidates previous regulations, including the Energy Saving Act (EnEG, 1976-2020), the Energy Saving Ordinance (EnEV, 2002-2020), and the Renewable Energies Heat Act (EEWärmeG, 2009-2020), into a unified framework. Compliance with the GEG is **mandatory** for both **new buildings and existing buildings undergoing major renovations**[35].

[31] Schlomann (2021)

[32] Art 2 (22) of the EPBD defines: 'major renovation' means the renovation of a building where: (a) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated; or (b) more than 25 % of the surface of the building envelope undergoes renovation. Member States may choose to apply point (a) or (b).

[33] Legislative Resolution of 12 March 2024 on the Proposal for a Directive of the European Parliament and of the Council on the Energy Performance of Buildings (Recast) (COM(2021)0802 – C9-0469/2021 – 2021/0426(COD)), 2024.

[34] European Union (2024)

[35] The major renovation refers to that more than 25% of the surface of the building envelope is undergoing renovation.

Key features of the GEG related to minimum energy performance requirements (MEPRs) include:

- **Setting requirements for the annual primary energy demand** of buildings, the energy performance of building envelopes, and the use of renewable energies.
- **Performance-based MEPR** for residential buildings, covering heating, cooling, and domestic hot water systems

The MEPR has been **progressively tightened over the years** to enhance energy efficiency in buildings

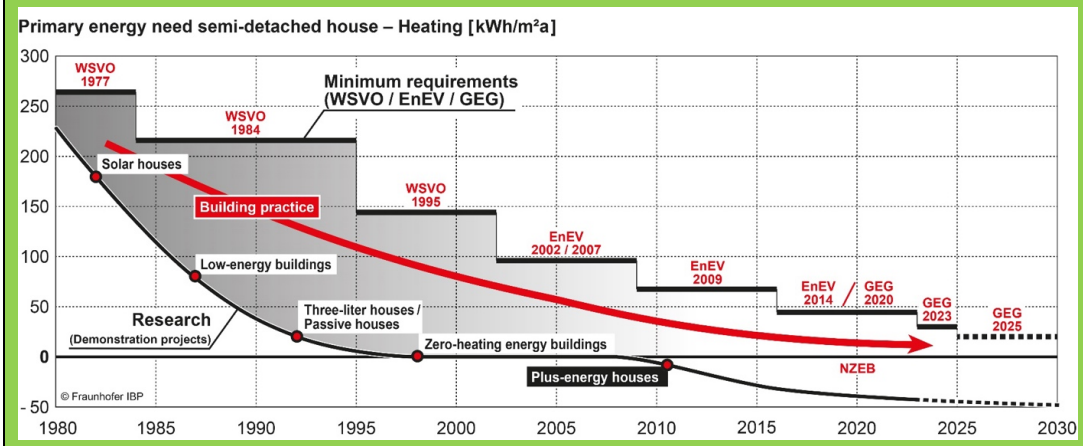

Figure 2: The development of Minimum Energy Performance Requirements in Germany

Source: Fraunhofer IBP (2022) [36]

While mandatory MEPR for new buildings has been in place for a long time, **minimum energy performance standards (MEPS) for existing buildings** based on EPC is still relatively new and MEPS for existing residential buildings are not yet mandatory, leaving their implementation to the discretion of individual Member States. Currently, only a few EU countries have explicitly integrated MEPS for residential buildings into their national regulations, e.g., France, Scotland (proposal), some regions in Belgium.[37]

Brussels-Capital Region of Belgium

The Brussels-Capital Region aims to achieve a **minimum EPC rating of C (<100 kWh/m²/year of primary energy consumption) for its entire building stock by 2050**. To comply with the mandatory MEPS scheme, building owners must implement a **prescribed number of energy efficiency measures within set timeframes**. Compliance is structured in **five progressive stages** between 2030 and 2050, with enforcement based on the recommendations outlined in EPCs. By each deadline set in legislation, owners must demonstrate that the required efficiency measures have been successfully implemented.[38]

France

The 2015 Energy Transition Law sets France on a path to align its building stock with the Bâtiment Basse Consommation low-energy standard or an equivalent benchmark by 2050. To achieve this, France has **introduced mandatory MEPS**, **gradually restricting the rental of inefficient properties.** Since **January 2023**, **rental of properties consuming more than 450 kWh/m²/year** has been **prohibited**. By **2028, all EPC F and G-rated dwellings**—representing 17% of the total housing

[36] Fraunhofer IBP (2022)
[37] EESC (2022)
[38] European Union (2020)

stock—will **no longer be rentable**. By **2034**, the ban will extend to **EPC E-rated** properties, which account for approximately 40% of the housing stock. These measures ensure a phased improvement in building efficiency while providing owners with a timeline to upgrade their properties.[39]

Beyond building energy codes, several European nations and regions have introduced **restrictions on fossil fuel heating systems in both new and existing buildings** to accelerate decarbonization efforts, for examples:

- **Austria**: A ban on the installation of central heating boilers using liquid or solid fossil fuels in new buildings has been implemented.
- **Norway**: Since 2020, the use of mineral oil for heating has been prohibited in both new and existing buildings, including the operation of existing oil-fired boilers.
- **Belgium (Flemish Region)**: Since 2022, the installation of fuel oil boilers has been banned for new buildings and major energy renovations in both residential and non-residential sectors.[40]

These regulatory measures complement broader European efforts to phase out fossil fuel-based heating systems and promote renewable energy and electrification in the building sector.

2.3.5 Financial incentives

In the EU, the EPBD requires Member States to identify and report to the European Commission on national financial measures to improve energy efficiency. **Subsidies for energy renovation and low-carbon heating systems** have been widely implemented **across all Member States**, supporting both homeowners and businesses in reducing building-related emissions. Additionally, **over ten Member States** provide **tax incentives**, including income tax deductions, tax credits for energy-efficient investments, and reduced VAT rates on renovation materials and services. Furthermore, **loans and low-interest financing options** are available for residential buildings in **19 Member States**, enabling broader access to funding for retrofitting projects. However, **for newly constructed buildings**, **only a few** national governments currently offer financing for the construction of **highly energy-efficient** buildings.[41]

Two examples are presented below: one from Germany, which includes both grants and loans, and another from Austria, which supports low-income households.

Germany: Federal Funding for Efficient Buildings (BEG)

The German government has been implementing funding programs to promote energy efficiency and renewable energy in buildings since the 1990s. In 2021, it established the Federal Funding for Efficient Buildings (Bundesförderung für effiziente Gebäude, BEG) as a central instrument to achieve its climate targets. The BEG consolidates previous programs into a unified framework, offering financial support for both residential and non-residential buildings. The Climate and Transformation Fund (Klima- und Transformationsfonds KTF) allocated €16.77 billion in 2024 and €16.86 billion for the BEG (according to the budget plan for the KTF).[42]

The BEG program provides funding in the form of low-interest loans and direct investment grants. The German state-owned Bank KfW (Kreditanstalt für Wiederaufbau) is the main implementing organization of the program. For the loans, KfW uses an on-lending approach, which means that it does not directly provide funding to final customers. Instead, it collaborates with intermediary financial institutions, mostly commercial or public banks. These intermediary banks assess the creditworthiness of clients and the viability of investments before on-lending KfW funds. Ultimately,

[39] European Commission (2023c)
[40] Braungardt et al. (2022)
[41] Xia-Bauer et al. (2024)
[42] https://www.bmwk.de/Redaktion/DE/Meldung/2023/20231221-haushalt-einigung-ktf-2024.html

KfW decides whether a specific loan application meets the criteria for promoting energy efficiency. While the credit risk remains with the on-lending banks, they receive an implementation margin within the KfW interest rate as compensation for their services.[43]

KfW implements governmental funding for a systematic approach to energy efficiency in residential and non-residential buildings, i.e., the purchase or construction of a new energy-efficient building/apartment and comprehensive energy renovation[44]. Key features of KfW's energy-efficient building loans include：

- **High threshold for energy efficiency and sustainability.** The recently adopted BEG has tightened the eligibility criteria for energy performance to ensure that only the most energy-efficient buildings can receive funding. For residential buildings, **new constructions** must meet the **Efficiency House Standard 40**[45] and be certified with the **German Sustainable Building Quality Seal** to qualify for funding. Energy efficiency **retrofits** are eligible for funding if they meet the **Efficiency House Standard 85 or better**.
- **Flexibility and low-interest rates.** With the annuity loan, the loan period is flexible and can range from **four to 30 years**. The low interest rate is fixed for the first ten years of the loan period. After this initial period, KfW offers the customer another interest rate option for a 10-year extension.
- **Repayment bonus tied to energy efficiency and renewable use**. It reduces the loan amount and shortens the repayment period. The higher the efficiency achieved in the renovation project, the higher the repayment bonus awarded to the owner.
- **Support for planning and construction supervision**. For loan applications, KfW requires the owner to engage a qualified energy efficiency expert for project design and construction supervision. The expert must then confirm that the project meets KfW's energy efficiency standards using online software provided by KfW. Additionally, KfW **subsidizes these technical services by covering 50%** of the eligible costs through an additional loan amount and a repayment grant.[46][47]

An amendment to the GEG, which came into effect on 1 January 2024, mandates that any newly installed heating system must utilize **at least 65% renewable energy**. The BEG provides subsidies to homeowners replacing old fossil-fuel heating systems with new, climate-friendly alternatives**. A base subsidy of 30%** is available for heating system replacements, with additional climate bonuses designed to accelerate the adoption of renewable heating solutions. These include:

- A "**climate speed bonus"** for replacing operational oil, coal, or old gas heating systems before 2028.
- An **efficiency bonus**, awarded for the installation of **highly efficient heat pumps**.
- A **grant** for **new, ultra-low-emission biomass** heating systems.
- An **additional 30% income bonus for households** below a certain income threshold to support affordability.

These stackable incentives can cover **up to 70% of the total investment costs**, significantly reducing

[43] Hennes (2018)

[44] Governmental funding can be provided for investing in both the whole-building energy efficiency projects and the individual measures. Another agency is responsible for funding individual measures.

[45] The term "Efficiency House" (Effizienzhaus) was introduced by the KfW as a benchmark for energy savings achieved, aligning with the general standards outlined in the German Buildings Energy Act (GEG) for both new constructions and existing buildings. These standards establish the minimum requirements for energy efficiency against which building projects are evaluated. Efficiency House Standard 40 signifies that a new or renovated building can only consume 40% of primary energy and have 55% of the transmission heat loss compared to a reference building.

[46] KfW (n.d. a)

[47] KfW (n.d. b)

the financial burden on homeowners.[48]

Austria: Clean Heating for All ("Sauber heizen für alle") program [49]

In 2022, the Austrian government launched the "Clean Heating for All" (Sauber Heizen für Alle) program, a targeted initiative aimed at **supporting low-income households** in switching to climate-friendly heating systems. The program provides **full financial support for replacing fossil fuel heating** systems with either:

- A **connection to a district heating** network, or
- Installation of a **heat pump** for homeowners in single-family, two-family, or terraced houses.

Eligibility and financial support

- **Full cost coverage** for households in the **lowest two income deciles** (income thresholds adjusted based on household size).
- **75% cost coverage** for households in the **third income decile**.
- **District heating first**: If a district heating connection is available, alternative heating systems do not qualify for funding.

The program covers a wide range of costs, including **materials, installation, planning, and the dismantling and disposal of outdated boilers and tank systems**. Beneficiaries can **combine the grant with local initiatives and additional incentives** for solar thermal installations. To qualify, homeowners must register their project proposals online, provide proof of eligibility, and complete a mandatory free energy audit. After upfront payment, beneficiaries can claim the subsidy upon project completion.

In **its first year**, the program replaced the heating systems for around **1,450 households**, transitioning from fuel oil, coal, or natural gas systems to **pellet-fueled central heating, biomass heating, or heat pumps**. This effort resulted in an **annual CO_2 reduction of about 11,000 tonnes**. The program has successfully reached **vulnerable households** by **improving the affordability** of efficient and environmentally friendly heating technologies while **reducing energy bills**.

Key factors contributing to the program's success include the **full cost coverage for eligible beneficiaries, comprehensive information and administrative support, and the involvement of energy advisors**. However, the program evaluation highlighted challenges for beneficiaries **lacking upfront funds** to cover costs before receiving the subsidy. To enhance accessibility and maximize impact, the program could **introduce a pre-financing mechanism or** assist beneficiaries to secure **bridging loans from financial institutions**, thereby removing financial barriers and ensuring greater accessibility.

2.3.6 Information provision and advice to building owners

The European Commission has promoted the energy services market through various policy measures, such as information dissemination, quality labels for ESCOs and the provision of model energy performance contracts.

In recent years, the concept of **One-Stop Shops (OSS)** has gained momentum within the EU as a holistic approach to assist homeowners and tenants in navigating the complexities of energy renovation.

[48] KfW (2024)

[49] More information about the program is available at the following links (European Commission, Directorate-General for Climate Action et al. 2024):

- Legal basis: https://gesetzefinden.at/bundesrecht/bundesgesetze/ufg
- Program website: https://www.umweltfoerderung.at/privatpersonen/sauber-heizen-fuer-alle-2024
- Evaluation report: https://www.bmk.gv.at/dam/jcr:55c72350-49e6-4c20-adbc-3d789680c391/Bericht_Wifo_SHfA_UA_v2.pdf

OSSs can offer **a range of services, including assessing building energy performance, helping clients select reliable contractors, facilitating financing, providing technical advice, overseeing project management, and ensuring quality assurance**.
They will usually need a core funding from the government but may also **operate as Energy Service Companies (ESCOs)** offering all-inclusive services or collaborate with local suppliers to help clients select reliable contractors. The revised **EPBD**, devotes an article to OSS, **defining their roles and mandating Member States** to develop these entities in cooperation with authorities and key stakeholders to ensure their **effective functioning and sustainable funding**. The OSS shall be **available nation-wide** and provide independent and comprehensive advice on energy-efficient refurbishment to households, SMEs and public bodies with **a particular focus on vulnerable households**, **people affected by energy poverty, and low-income households**.
Similarly, the revised **Energy Efficiency Directive (EED)**, adopted in September 2023, emphasizes the creation of OSS, along with the provision of technical and financial advice and consumer protection measures.[50]

France: Régie du SPEE – a One-Stop-Shop in Hauts-de-France[51]
The "Régie du SPEE" was established in 2013 by the former Picardie Region as a dedicated service provider to **support homeowners, landlords, tenants, and homeowners' associations in undertaking energy renovations and energy-saving measures**. This initiative ensures inclusive access to renovation services, **regardless of building type, financial means, or property age**.
The Régie du SPEE operates **two key programs**:

- Pass Rénovation: **Tailored for individual building owners**.
- Pass Copropriété: Designed to **assist homeowners' associations** in collective renovation projects.

Beyond technical guidance, the Régie du SPEE also **provides financial solutions**, ensuring that all interested parties can successfully implement energy-efficient refurbishments. Projects are **structured step by step** to **facilitate the necessary voting procedures** within homeowners' associations.
Since 2013, the program has had significant impacts:

- **6,500 households** have sought information and guidance.
- **More than 3,000 energy audits** have been conducted.
- **880 houses** have been renovated, with a total investment of €40 million (averaging €45,000 per project).
- **Average energy savings of 52%**, with **energy cost reductions covering approximately 60% of the monthly loan repayments** (average loan amount: €30,000).
- **31 condominium owners' associations**, representing over 2,700 households, have engaged with the Régie du SPEE for energy renovation support. Of these, **14 associations** (1,073 apartments) have initiated or **completed renovation projects**.

Through these efforts, the **annual GHG emissions reduction** amounts to approximately **6,000 tonnes**, demonstrating the program's effectiveness in advancing large-scale residential energy efficiency.

Another important information tool used in Member States is the **building renovation passport (BRP)**, which describes a customized long-term step-by-step renovation plan for a specific building. Article 2 of the EPBD defines a 'renovation passport' as a **"a tailored roadmap for the deep renovation of a**

[50] European Commission (2023b)
[51] Morcrette (2022)

specific building in a maximum number of steps that will significantly improve its energy performance". The BRP is designed to support building owners and investors determine the optimal timing and scope of energy renovation measures. The EPBD (Annex VIII) proposes a common framework for BRP across Member States. By May 2026, BRP should be made available to building owners as **a voluntary tool** based on the EPBD framework (EPBD, Art. 12). Several EU countries, including Germany, France, and Belgium, have already adopted BRP schemes, although their specific designs vary.

Germany: Individual Renovation Roadmaps

Germany offers a comprehensive approach to building energy efficiency through building-specific roadmaps for staged 'deep' renovation'. The so-called Individual Renovation Roadmap ("Individueller Sanierungsfahrplan") (iSFP) is a **clear and structured plan for property owners to implement a step-by-step renovation** on the way to an Efficiency House. The iSFP is tailored to the specific needs of the building, outlining steps for energy renovation and their optimal sequence for single and two-family houses as well as apartment buildings. The iSFP is **voluntary, but is incentivised by an 50% subsidy** from the German government under the BAFA's Federal Energy Advice Scheme for Residential Buildings. To qualify for this financial support, the **energy advisor must be officially recognized** as an energy efficiency expert listed in the national database.[52] The process of developing an iSFP involves six steps:[53]

1) **Initial advice**: An **on-site** meeting is conducted between the energy efficiency expert and the homeowner to **assess renovation needs**. The consultation considers both **energy-related and non-energy-related aspects,** such as building adaptation for aging residents, expanding living space, or enhancing overall living comfort.
2) **Building energy assessment**: The expert performs an **in-depth analysis** of the home's **current energy performance**, identifying inefficient building components and providing an **initial assessment of renovation**.
3) **Development of renovation proposals**: The expert **designs tailored renovation packages**, outlining optimal sequencing and estimated costs for each measure. The iSFP remains valid for **up to 15 years**; after this period, property owners will no longer be eligible for additional funding bonuses for implemented measures.
4) **Creation of the Individual Renovation Roadmap**: The expert collaborates with the property owner to evaluate different renovation measures and **compiles a structured iSFP** document outlining the recommended steps.
5) **Final advice and documentation**: The energy efficiency expert presents the final iSFP, ensuring the homeowner fully understands the recommended measures, costs, and benefits. Property owners receive a comprehensive set of documents, including:
    - "My renovation roadmap" – with clear information on the current state of the building and the planned renovation steps.
    - "Implementation guide for measures" – with detailed information on the individual renovation steps including the respective efficiency measures.
6) **Implementation and renovation**: Before proceeding with the implementation of any measure outlined in the iSFP, property owners can apply for a grant through BAFA. The funding rate for the respective measure is increased by an additional 5% when implemented as part of an iSFP. To qualify for this bonus, the measure must be completed within 15 years of the iSFP's issuance. Additionally, the maximum grant amount increases from €4,500 to €12,000 when applying under an iSFP.

[52] BMWK (n.d.)
[53] KfW (n.d. c)

An iSFP therefore offers a number of benefits to homeowners and reflects Germany's commitment to reducing energy consumption and carbon emissions in the building sector. By providing **detailed, step-by-step plans and substantial financial support,** Germany is facilitating the transition to more energy-efficient buildings. This will enable property owners to undertake significant renovations.

3. Decarbonising Residential Buildings in China

3.1 Energy Landscape of the Chinese Residential Building Sector

China's residential building stock is vast and continues to expand. According to the International Energy Agency[54], the **total building stock is projected to grow by approximately 40% by 2060.** In addition, much of this stock is relatively young and will remain in use for decades.

The residential sector accounts for a major share of China's building energy consumption, consuming 20.5 million terajoules (TJ) in 2022, or 59% of the sector's total energy use. Urban areas contributed 13.2 million TJ of this consumption, while rural areas accounted for 7.3 million TJ. While rural buildings have lower carbon emission intensity—21.9 $kgCO_2/m^2$ in 2022, compared to 25.4 $kgCO_2/m^2$ in urban areas—they often suffer from poor insulation and low energy performance, leading to significant heat loss and inefficient energy use.[55]

3.2 Strategies for Residential Building Decarbonization in China

A dual strategy is required to improve the energy performance of China's residential buildings:

- **Enforcing high energy standards for new constructions and actively promote ultra-low energy, near-zero energy, low-carbon, and zero-carbon buildings.** In regions such as Beijing-Tianjin-Hebei and the Yangtze River Delta—the large-scale development of ultra-low energy buildings should be accelerated. By 2025, the floor area of newly constructed ultra-low and near-zero energy buildings is expected to increase by 200 million m^2. [56]
- **Enhancing the energy efficiency of existing buildings and scale up renovation.** For residential buildings built before 2000, efforts should focus on upgrading key energy-consuming equipment such as air conditioning, lighting, and elevators, as well as improving external wall insulation and replacing windows and doors. In rural areas, more cost-effective short-term solutions involve targeted renovation—for example, partial insulation improvements. Insulating north-facing walls, doors and windows, and roofs can achieve up to 30% energy savings. This is particularly effective in northern regions, where many households only heat one or two rooms during winter. [57]

By 2030, retrofitting should be carried out across existing buildings to significantly improve their energy performance. In rural China, in the short term, targeted solutions such as partial insulation renovations are more cost-effective.[58] For example, insulating north-facing walls, doors, windows, and roofs can achieve up to 30% energy savings, especially in northern regions, where many households only heat one or two rooms during winter.[59]

Another key pillar of building decarbonization in China is the transition to low-carbon heating systems, primarily through **electrification and district heating**.

- In **northern urban areas** with high heating demand, the share of **low-carbon heating** (heat pumps and district heating) should **exceed 70% by 2030 and surpass 90% by 2060**.
- In other urban areas, **heat pump adoption** should reach **nearly 100% by 2060**.
- **By 2030, electricity consumption** is expected to account for more than **65% of total building energy use.** [60]

In **rural China,** two key low-carbon heating options stand out:

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[54] IEA (2021)
[55] THUBERC (2024)
[56] MoHURD (2024a)
[57] Energy Foundation China (2022)
[58] You et al. (2023); Guo et al. (2022)
[59] Energy Foundation China (2022)
[60] MoHURD (2022)

- **The utilization of modern biomass**, i.e., biomass pellets and modern stoves, for rural house heating has huge potential. In China, agriculture produces about 674 million tonnes of straw and 110 million tonnes of agricultural waste annually. In addition, there are 140 million tonnes of forestry waste, 3.81 billion tonnes (wet weight) of animal and poultry manure, and 340 million tonnes of solid waste, totalling around 27 million TJ.[59]
- Rural China represents one of the highest potentials for **decentralized heat pump** deployment. According to projections by the International Energy Agency (IEA), sales of air-to-water heat pumps in rural regions are expected to increase seven-fold by 2050, while air-to-air units specifically designed for space heating are projected to experience even greater growth.[61]

3.3 Policies for Residential Building Decarbonization in Rural China

China has implemented a comprehensive set of policies to improve energy efficiency and reduce emissions and promote low-carbon heating in the residential sector, including rural areas. Key initiatives include building decarbonization strategies, mandatory building energy codes, building energy labelling, and financial incentives for large-scale renovation and clean heating programs, which will be outlined in this section.

3.3.1 Overarching targets

Central to China's building decarbonization efforts is the **Carbon Peak Action Plan for the Building Sector**, introduced in 2022. This plan defines specific energy-saving goals by 2030, including a mandate for **new residential buildings in severe cold and cold regions** to meet **83% energy-saving standards**, while **buildings in hot summer/cold winter, hot summer/warm winter, and moderate climate zones must achieve 75%** energy-saving standards.[62] In addition, the plan promotes the **construction of green and zero-carbon rural homes**. In **northern regions**, energy retrofitting efforts aim to achieve a significant improvement in overall energy performance, **exceeding 30%**.[63] All provinces are required to detail the Action Plan tailored to their conditions.

In addition, the implementation of the Action Plan is also supported by the **Five-Year Plan (FYP)** of both national and provincial governments. For instance, as stated in the national 14th FYP, it aims to achieve **energy retrofitting of existing residential buildings covering an area exceeding 100 million m2 by the year 2025**.[64]

The national government has established **technology roadmaps for clean heating of residential buildings in northern China**, which are continuously refined based on the results of pilot programs. **The first phase** focused on **replacing coal with electricity and gas** to reduce reliance on traditional energy sources. **The second phase** introduced **region-specific** solutions, **prioritizing renewable energy sources** such as geothermal, biomass, solar thermal, and photovoltaics to suit local conditions. **The third phase** adopts a **flexible and diversified strategy, balancing the use of electricity, gas, and coal** as contextually appropriate. This phase also emphasizes the promotion of **advanced heating technologies**, including **centralized electric heating systems, storage electric heaters, and air-source heat pumps**.

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[61] IEA (2024)

[62] An X% energy-saving standard refers to the reduction in energy consumption for space heating compared to reference buildings from the 1980s.

[63] Government of China (2022)

[64] MoHURD (2022)

3.3.2 Pricing mechanisms

China introduced its inaugural **national ETS** in 2021, covering 32.6% of national GHG emissions.[65] The **building sector remains excluded** from this framework. Besides, China has also **not introduced a carbon tax**.

In China, **energy prices are regulated by local governments**. **Residential electricity rates are kept low**, ranking among the lowest globally, as a measure of social welfare.[66]

In 2017, as a part of the clean heating program in northern China, the central government **encouraged local governments to implement measures promoting heating electrification** in the residential sector. The objective was to reduce the cost of clean heating electricity **by refining time-of-use (TOU) pricing systems and innovating electricity market mechanisms**. For instance, under the TOU system, it is recommended that **off-peak hours for heating electricity should be extended by up to two hours.** Additionally, **increasing the price difference between peak and off-peak periods** is proposed to further encourage electricity consumption during off-peak hours throughout the heating season. In 2021, a national policy was issued to **mandate local governments to establish ToU pricing for retail customers**, including residential users. The extension of off-peak hours for heating is again highlighted.[67] Additionally, electricity used for clean heating is encouraged to **actively integrate into the power market,** promoting **demand-side flexibility**.

In regions with abundant wind and solar resources, **enterprises engaged in electric heat storage and other energy storage solutions are incentivized** to establish **direct transactions with renewable power generation companies**. At the provincial level, **Gansu Province** has introduced a set of targeted policies to support clean heating electricity. Residential heating electricity is priced under a ToU system, offering **lower off-peak rates during both daytime and nighttime hours**. For **centralized electric heating enterprises primarily serving residential consumers, electricity prices are categorized under the large industrial tariff** for equipment with transformer capacities of 315 kVA or more, making them lower than standard industrial and commercial electricity rates. Furthermore, **electric heat suppliers** are encouraged to participate in **power market transactions**, benefiting from reduced costs during off-peak periods. These enterprises receive a **50% reduction in network charges** for the corresponding voltage level and a **50% reduction in capacity charges**, further lowering operational costs.[68]

Regarding residential heating pricing, in most regions with district heating systems, **residential heating prices are typically determined based on floor area** rather than actual energy consumption. To accelerate building sector decarbonization, the government has promoted the **gradual transition to metering-based billing** in residential buildings where feasible. For existing residential buildings where in-unit heat metering retrofits are either technically impractical or cost-prohibitive, **building-level metering may be implemented as an alternative**. Meanwhile, **newly constructed buildings** in northern district heating regions are **required to comply with heat metering standards**.[69]

3.3.3 Building Energy Codes and Building Information Disclosure

Building Energy Codes

China introduced its **first residential building energy code in 1986**, setting a 30% energy-saving target for space heating compared to energy consumption 1980s reference buildings. **Over time, the residential energy codes have been progressively strengthened** across the country's **five distinct**

[65] OECD (2022)
[66] OECD (2019)
[67] The Government of China (2021)
[68] Gansu Provincial Development and Reform Commission (2021)
[69] MoHURD (2024a)

climate zones—Hot Summer and Cold Winter, Hot Summer and Warm Winter, Cold, Severe Cold , and Moderate. These codes have undergone multiple revisions to achieve higher energy efficiency standards, with increasing savings targets. The energy efficiency requirements for new buildings have increased from 30% to 50%, and then to 65%.

In 2021, the national government updated the energy efficiency guidelines:

- **New residential buildings in HSCW and HSWW** must achieve **65% energy savings.**
- **New buildings in Cold/Severe Cold (C/SC) zones** must meet **75% energy savings**.[70]

In 2022, regions such as Beijing and Shandong in northern China fully implemented energy efficiency standards exceeding 80% for residential buildings. With the Ministry of Housing and Urban-Rural Development (MoHURD) promoting the large-scale adoption of ultra-low and near-zero energy buildings, these standards have now been raised to over 85%.

Further strengthening these targets, the 2022 Carbon Peak Action Plan established ambitious long-term goals:

- By 2030, **new residential buildings in C/SC zones** must reduce energy consumption by **83%,**
- In **all other zones**, energy consumption must be cut by **75%.**

Building energy codes remain **mandatory only for new urban residential buildings**, while **rural houses have historically been exempted**. However, in the 14th Five-Year Plan (FYP) issued in 2022, the MoHURD[71] emphasized the enforcement of energy codes for rural residential buildings. China's **rural energy efficiency standards** fall into two key categories:

- **Guidelines**: These **non-binding** frameworks provide **technical recommendations** for green, low-carbon rural buildings, offering design and construction guidance for professionals.[72]
- **Design Standards**: These standards include the **Energy Efficiency Standard for Rural Residential Houses** issued by the national government, supplemented by region-specific energy efficiency codes. They serve as the basis for site selection, building envelope design, energy use structure, as well as lighting and air conditioning systems.

  In addition, there are also a set of green rural houses evaluation standards use to assess whether rural houses achieve the desired level of sustainability.[73]

In terms of policy design, these standards above—applicable to both urban and rural areas—mostly follow a **prescriptive-based** approach, specifying performance requirements for individual building technologies and components (e.g., building envelope, HVAC systems). However, there is no minimum overall energy consumption threshold.

The **Energy Quota Standard of Civil Buildings (EQS),** introduced in 2016, marked a shift towards a **performance-based approach**, becoming China's first national policy to assess actual energy use intensity rather than relying solely on design specifications.[74] The EQS applies to both residential and non-residential buildings across different climate zones, providing a framework for evaluating real-world energy consumption. However, the EQS remains voluntary for both new and existing buildings, with data collected over a one-year period but lacking enforcement mechanisms such as compliance measures or penalties. As a result, its implementation has been limited to pilot projects in select major cities, and it has **yet to achieve widespread adoption** at the national level. Besides, in 2019, the voluntary standard for ultra-low energy and near-zero energy buildings was launched. For residential buildings, these standards set threshold of total energy consumption as well as specific energy uses (heating, cooling, and renewable energy). In addition, they also provide guiding benchmarks for

[70] MoHURD (2021)

[71] MoHURD (2022)

[72] For example, the Guidelines for Green Rural Housing Construction (Trial Version) (2013) and the Technical Guidelines for Energy Efficiency in Rural Housing in Severe Cold and Cold Regions (Trial Version) (2009)

[73] For example, the Evaluation Standard for Green Villages (T/CECS 629-2019), and the Technical Standards for Green Rural Housing Construction (2021, Shandong).

[74] MoHURD (2016)

building design, the thermal performance of the building envelope, and the efficiency of energy systems.

Building Energy Information Disclosure

To enhance transparency in building energy performance, China introduced the **Building Energy Efficiency Evaluation and Labelling (BEEL)** system in 2008. This system underwent a trial phase and technical guideline amendments in 2012.[75]

BEEL informs potential buyers about **annual heating and cooling demand, expected energy savings (design vs. actual performance), and a rating system from 1 to 3 stars (1 = low, 3 = high performance).** The BEEL energy savings indicator **aligns with building energy codes**—for example, buildings that achieve 65% or more energy savings in designated climate zones qualify for a 3-star rating. Although the system applies to both new and existing buildings, BEEL **remains voluntary** for residential buildings. Due to challenges in assessment and certification, its **adoption has been limited**, hindering its effectiveness in driving widespread energy efficiency improvements.[76]

3.3.4 Financial incentives

The **National Pilot Program for Clean Heating,** launched in 2017, subsidizes **the upfront costs of energy retrofits,** as well as **expenses for clean heating and cooking equipment and fuels.** This initiative is funded by the **National Air Pollution Prevention and Control Fund,** which is **renewed annually and allocated to designated pilot cities**.[77] **Local governments** are required to **provide matching funds** to support implementation at the regional level.

Between 2017 and 2021, **the national government allocated over RMB 62 billion to more than 60 pilot cities**.[78] Building on this initiative, an additional **88 pilot cities received a cumulative RMB 108.3 billion** in funding between 2022 and 2024.[79]

However, in rural areas, a significant part of the **subsidy has been used for fuel switching**—substituting coal and traditional biomass with clean heating sources, rather than improving overall building energy performance. A 2021 survey found that **only 12.4% of subsidies were allocated to building envelope retrofits**, resulting in limited progress in energy renovation (National Energy Information Platform, 2021).[80] Additionally, **natural gas has been classified as a clean fuel**, making the purchase and use of natural gas boilers eligible for partial subsidies.[81] As a result, by 2022, approximately 52% of households in northern plain regions (around 25 million households) had switched from coal to natural gas.[82]

Beyond clean heating initiatives, another national funding source provides **subsidies to selected pilot cities for urban renewal projects**, which include energy retrofitting of residential buildings. Under the 2024 funding program, **each pilot city receives subsidies ranging from RMB 800 million to RMB 1.2 billion.**[83] However, detailed information on the allocation or breakdown of these expenditures remains unavailable.

[75] MoHURD (2012)
[76] Xia-Bauer et al. (2024)
[77] Ministry of Finance P.R. China (2023)
[78] Environmental Planning Institute of MEE (2022)
[79] Chinese Government (2023, December)
[80] National Energy Information Platform (2021)
[81] Beijing Sustainable Development Promotion Association & Zhongke Huayue ERI (2021)
[82] Environmental Planning Institute of MEE (2021)
[83] MoHURD (2024b)

4. Insights to Accelerate the Decarbonization of China's Residential Building Sector

Policymakers in the EU and China have established comprehensive but distinct policy frameworks and strategies for residential building decarbonization. Both the EU and China have established policy roadmaps for decarbonizing the residential building sector, addressing new and existing residential buildings. The EU's roadmap emphasizes energy renovation of buildings as a cornerstone of its strategy, aligning with its 2050 climate neutrality target. China, while also promoting energy retrofitting of its existing building stock, primarily focuses on strengthening the stringency of the energy performance of new buildings aiming to achieve its 2030 carbon peak objective. This section explores policy similarities, analyzes key success factors of EU policies, and highlights lessons learned that could inform and enhance China's policies and accelerate progress towards decarbonization.

Building Energy Codes: Expanding Coverage to Include Existing Buildings and Rural Areas

China's Minimum Energy Performance Requirements (MEPRs) are primarily focused on new residential buildings, with stringent energy efficiency standards that have significantly improved the performance of newly constructed homes. This approach aligns with China's rapid urbanization and high new construction rates, ensuring that the expanding building stock is energy efficient. However, the absence of mandatory MEPRs for existing buildings presents a major policy gap.

The EU, by contrast, has established mandatory MEPRs not only for new buildings but also for existing residential buildings undergoing major renovations if technically, functionally and economically feasible. This dual focus reflects the EU's recognition of the critical role of retrofitting in achieving long-term decarbonization, particularly in regions with aging building stocks and low rates of new construction. However, it is important to note that the EU's mandatory MEPRs for existing buildings apply only to those buildings undergoing major renovations, while Minimum Energy Performance Standards (MEPS) for existing residential buildings remain non-mandatory at the EU level. That said, several EU Member States have proactively introduced MEPS, demonstrating leadership in enhancing the energy performance of the existing housing stock.

China holds immense potential for energy savings and decarbonization through residential building retrofitting, particularly in urban areas with aging housing stock and rural regions lacking energy performance standards. The EU's approach, especially the pioneering Member States that have adopted mandatory MEPS for existing buildings, offers valuable insights for China as it seeks to enhance its policy framework for energy renovation of existing residential buildings.

To accelerate building sector decarbonization, we suggest that China should consider a step-wise approach of introducing mandatory MEPRs for existing residential buildings, particularly those undergoing major renovations. The rationale behind this is the fact that if, as an example of a major renovation, a roof is being renovated, it will usually be cost-effective to add insulation levels equal or similar to those required for new buildings. The case of an external wall will be similar, and for the replacement of windows, the extra cost of windows with lower heat transmission values may be small. Expanding MEPRs to rural housing, coupled with targeted support for citizens in terms of information provision, energy advice and financial support, would further enhance decarbonization efforts. This would require a tailored strategy that considers the unique characteristics of rural housing, including traditional construction methods, locally available materials, and economic constraints, ensuring feasibility and widespread adoption. A study of typical buildings could identify typical staged deep renovation roadmaps, which could guide both advice, financial support, and MEPRs.

Building Energy Codes: Transitioning from a Prescriptive- to a Performance-Based Approach

China's building energy codes have historically been based on relative reductions compared to typical energy consumption levels calculated in the 1980s, and prescriptive-based. This approach has its

limitations, as it does not support holistic energy efficient design. While prescriptive standards are straightforward to implement and enforce, they may limit innovation and adaptability.
Some EU Member States such as Germany, have adopted a performance-based approach. The revised EU EPBD in 2024 has also integrated performance-based MEPS. This approach offers greater flexibility in design, encouraging innovation in achieving energy efficiency targets. It allows builders and designers to implement cost-effective and context-specific solutions, taking into account building type, location, and usage patterns. Drawing inspiration from the European and global experience, China began promoting nZEBs in 2019. It released its first technical standard for nearly zero-energy buildings. This standard broke from the conventional reliance on relative savings by introducing absolute overall energy consumption thresholds, alongside performance indicators serving as recommended benchmarks. This marked a significant shift, enabling more comprehensive control over both the design and operational phases of buildings. It is recommended that China accelerate its transition toward a performance-based building energy codes based on the existing nZEB standard.

Enhancing Policies for Information Provision and Advisory Services

The revised EPBD uses EPCs as a standardized metric for MEPR for residential buildings across the EU. Beyond providing energy performance information, EPCs offer tailored recommendations for energy efficiency improvements, helping property owners identify cost-effective measures to enhance energy performance. Germany's Individual Renovation Roadmap (iSFP) takes this concept a step further by offering property owners structured, step-by-step renovation plans. These roadmaps facilitate phased upgrades, allowing homeowners to prioritize measures based on feasibility, cost, and impact. By breaking down renovations into manageable stages, they improve long-term investment planning and align with national energy efficiency targets, such as achieving nearly zero-energy buildings by 2050. Complementing these tools, One-Stop Shops (OSSs) backed by EU legislation, such as those in Hauts-de-France, provide comprehensive support to property owners and investors navigating the energy renovation process. OSSs act as centralized hubs, offering technical advice, financial guidance, and access to qualified contractors, thereby simplifying the renovation journey and increasing renovation rates.
In contrast, China's current policy framework places a strong emphasis on regulatory instruments. The EU's multi-faceted policy approach that includes also information provision and advisory services offers valuable insights for China to enhance support for property owners and investors in planning and implementing energy renovations. For instance, China could promote local advisory centres to bridge the gap among different stakeholder groups. These centres would serve as centralized hubs, offering comprehensive support to streamline the energy renovation process. Specifically, they could:

- Facilitate collaboration between property owners, investors, and qualified technical companies to develop structured, step-by-step and cost-effective energy renovation roadmaps.
- Streamline access to renovation subsidies and other financing mechanisms, to address financial barriers for investment.
- Pool smaller renovation projects into larger portfolios, creating economies of scale and attracting greater interest from investors

Improving Financial Incentive Schemes: Diversification, Performance-Based Support, and Social Inclusion

Subsidies are an important part of the policy package to residential building decarbonization in both the EU and China. While they effectively drive early-stage adoption of energy efficiency measures and clean heating technologies, their ability to mobilize large-scale investments is often limited.[84] Recognizing this, the EU has increasingly integrated preferential loans into its policy mix. For example,

[84] Bertoldi et al. (2021)

Germany's combination of grants and low-interest loans has successfully accelerated building renovation efforts. China has also acknowledged the potential of green financing, with banks piloting green loans and green funds for clean heating projects. However, wider adoption remains limited.

A key lesson from the EU is the importance of linking financial incentives to high energy performance. For instance, Germany's KfW program sets stringent eligibility criteria for its loans, ensuring support is directed only to highly energy-efficient technologies like heat pumps and advanced insulation. This performance-driven approach maximizes energy savings and environmental benefits while ensuring cost-effective use of public funds. Beyond financial incentives, advisory support is critical. KfW integrates subsidies for expert guidance, ensuring renovation projects are well-designed, cost-effective, and systematically implemented. China could enhance its financial incentives by introducing similar support for qualified energy renovation advice, helping homeowners navigate the complexities of energy retrofits.

From a social perspective, full cost coverage for eligible low-income households, as seen in Austria's Clean Heating for All program, ensures that vulnerable populations benefit from clean heating and energy efficiency upgrades. China's clean heating program has made significant strides in reaching low-income households, but attention must be paid to addressing financing gaps in building envelope retrofits and avoiding lock-in to heating systems with high operational costs.

Overarching Instruments: Carbon Pricing and Energy Pricing

Carbon pricing remains a key policy divergence between the EU and China. Several EU Member States have already implemented carbon pricing for fuel use in buildings, and the EU's ETS2 will extend this mechanism to the building sector of the whole EU by 2027. Sweden's carbon tax model highlights the importance of predictability, as gradual tax rate increases allow households and businesses to adapt, minimizing economic disruption. To mitigate social impacts, the EU has also established the Social Climate Fund (SCF) to complement the expansion of the ETS2, supporting vulnerable households in the transition. This framework underscores the EU's commitment to balancing ambitious climate goals with social considerations.

In contrast, China has not yet introduced or planned carbon pricing for the buildings sector, relying instead on direct subsidies and regulatory measures. Unlike fuel bans or subsidy-driven approaches, carbon pricing provides a market-driven mechanism that delivers long-term price signals, encouraging sustained investments in energy efficiency. Exploring the potential role of carbon pricing in the building sector in China, along with complementary social policies, could be an avenue for future policy development. It should also not replace the specific policy mix of financial incentives, financing, advice and building energy codes for energy efficiency renovation and decarbonized heating, but complement it. The revenues from carbon pricing can be used to fund the buildings policy mix. This use of funds for decarbonization is also mandated in the EU's legislation for both EU ETS1 and ETS2.

To promote electrification in residential buildings, China has maintained low residential electricity prices, enhanced Time-of-Use (ToU) pricing, and incentivized direct transactions between electric heat storage enterprises and renewable power producers. Dynamic or ToU pricing as well as direct transactions between electric heat storage—at the level of individual buildings or district heating enterprises—and renewable power producers are approaches that the EU should also pursue further. While it is important for the breakthrough of heat pumps to limit the spread between electricity and fuels prices (e.g. gas or coal) to less than a factor of around three[85], any subsidies for electricity should be limited to energy-efficient electrification technologies, such as heat pumps, in order not to reduce incentives to use energy efficiently in other applications, such as home appliances or information and communication technologies.

[85] Cf. KfW (2025)

In most regions with district heating systems, residential heating prices are still based on floor area rather than energy consumption. To incentivize a more efficient user behaviour as well as investments in energy efficiency improvements and accelerate building sector decarbonization, the government must expedite the transition to metering-based billing, aligning heating costs with actual energy consumption. Decarbonizing the supply of district heating, e.g., from larger heat pumps that may also use the soil as a heat source, biomass boilers in rural areas, solar thermal installations, or waste heat, will also be important.

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