NDC ASPECTS

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Barriers and Policy analysis: Building Decarbonisation (Deliverable 4.3)

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Preface

The NDC ASPECTS project will provide inputs to the Global Stocktake under the Paris Agreement (PA) and support the potential revision of existing Nationally Determined Contributions (NDCs) of the PA's parties, as well as development of new NDCs for the post 2030 period. The project will focus on four sectoral systems that are highly relevant in terms of the greenhouse gas emissions they produce yet have thus far made only limited progress in decarbonization. To advance these transformations will require to understand and leverage the Eigenlogic of those systems and take into account specific transformation challenges. These sectors are transport & mobility (land-based transport and international aviation & shipping), emission intensive industries, buildings, and agriculture, forestry & land-use, including their supply by and interaction with the energy conversion sector.

1. Changes with respect to the DoA

None

2. Dissemination and uptake

See cover report

3. Short Summary of results

See cover report

4. Evidence of accomplishment

This report

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Executive Summary

Buildings are crucial in climate mitigation due to their significant share in final energy consumption and GHG emissions. However, the sector decarbonisation has been slow to move. This study aims to identify key barriers to building decarbonisation and analyse policy instruments addressing these barriers. In addition, the study also briefly discussed the contribution of building decarbonisation to SDGs as enablers for taking up the decarbonisation measures.

The research begins by synthesizing existing literature to identify key barriers for three building mitigation strategies on a global scale: improving building envelope performance, transitioning to low-carbon heating, cooling, and cooking systems, and adopting energy-efficient appliances and lighting. The report then examines how various policy instruments, including governance and planning measures, regulatory frameworks, economic incentives, market-based approaches, and capacity-building initiatives, address these barriers. On the global level, the research also analysed the interactions between all building mitigation strategies (the three above, sufficiency, and minimising embodied carbon of building materials) and SDGs and found these strategies could direct be linked to 12 SDGs. The co-benefits that contribute to SDGs could potentially enable mitigation in the building sector

As the second step, the research analysed the same categories of key barriers in ten selected countries. The identified barriers align closely with the global findings, although certain barriers are specific to particular countries. The report maps and compares policy measures implemented by each country to address these barriers. Most countries employ a mix of policies, with the European Union (EU) demonstrating the most comprehensive approach, followed by China and the United States.

Regulatory instruments are the most popular. All countries have building energy codes and MEPS for appliances and equipment. However, for building energy codes, except for China, the US, and the EU, the compliance rate is low in most countries. Besides, although all countries have MEPS, the numbers of appliances with MEPS vary significantly across the countries. Three countries (the EU, China, and Japan) out of six countries with significant heating demand have policies to ban fossil fuel boilers in buildings. Except for regulations, information instruments such as appliance labelling, which is often implemented with MEPS, are found in all countries, showing similar variations as the MEPS. Another common instrument is building information disclosure, except in Vietnam and Indonesia. Most countries have implemented at least some economic instruments, among which subsidies/grants are most common. Furthermore, most countries have implemented government lead-by-example through regulations, national strategies, or projects. While the above-mentioned regulatory, information, economic, and lead-by-example instruments have been widely implemented, several policy instruments have only been applied in a few countries: policy roadmaps, phasing out fossil fuel subsidies, energy efficiency obligations (EEOs), ESCOs policy package, One-stop shops (OSS), RD&D policies, carbon pricing for heating fuel. Based on the findings, we provided recommendations for enhancing commonly deployed instruments and for developing missing policies drawing on good practices observed in other countries.

The report concludes by acknowledging its limitations and suggesting areas for future research to further explore building decarbonisation policy measures in greater depth.

Contents

1 Introduction

As of 2019, buildings accounted for 31% of global final energy demand (128 EJ). Global GHG emissions from buildings amounted to 12 Gt CO2-eq, 21% of total global emissions, of which 24% were direct emissions. (Pathak et al., 2022). Thus, buildings are vital for achieving the Paris Agreement. So far, however, energy demand in buildings has continually increased, driven by building floor growth in combination with improved energy access and living standards (IEA, 2021f). Buildings are responsible for around 55% of global electricity use, which is projected to rise further, given the increasing access to space cooling and heat pump application (UNEP, 2020). Beyond the operation of the buildings, their construction causes massive indirect emissions arising from construction and manufacture, which are responsible for 10% of global energy-related CO_2 emissions (IEA, 2021f).

The report 1) synthesises the latest available scientific knowledge on key barriers for building decarbonisation and suitable policy options at the global level; 2) compares barriers and enablers as well as policy packages for building decarbonisation across ten countries/regions by assessing the *current* landscape of policy instruments and policy intensity of selected policy instruments.

2 Main mitigation strategies in the building sector

To achieve the Paris Agreement target, the building sector needs to be decarbonized through the following five interlinked strategies:

1) First and foremost, improving **building envelope performance** is the most important measure to reduce heating and cooling demand and is thus key for building decarbonization. Most important is thermal insulation against cold and heat, but energy-efficient ventilation, if possible, with heat/cold recovery, and optimizing solar gains and solar shading are also important. All of these options need to be adapted to the respective climates. New construction offers the best opportunity for deploying energy efficient envelope. For existing buildings, energy renovation needs to be deepened and accelerated(OECD/IEA, 2013).
2) Shift from fossil-fuel-based and low-efficient to low carbon **heating, cooling, and cooking**:
   - Space and water heating and space cooling (including district heating and cooling): For space heating, first, electrification through heat pumps becomes the key technology option to reach net zero emissions. It allows for the use of renewable electricity and is highly efficient, if buildings are well insulated (Bloess et al., 2018). Second, the direct use of renewable energies is expected to increase significantly(IEA, 2021e).

     Key strategies for decarbonizing space cooling at the building level include increasing energy efficiency of cooling equipment and the dominant use of ultra-low GWP refrigerants (Carbon Trust, et al., 2020; IEA, 2018, 2021e) . Besides, solar cooling solutions, including air conditioners powered by PV and solar thermal collectors combined with a chiller, are emerging technologies with zero or very low GHG emissions(IEA, 2018).

     Beyond the building level, district heating and cooling based on the direct use of renewable energy, excess heat, and renewable electricity represent important options for decarbonizing buildings, in particular, in compact urban areas(Fonseca & Schlueter, 2015; IEA, 2018)

     Both heat pumps and cooling equipment as well as district heating and cooling based on electricity can provide flexibility to the power system and thus help the integration of increasing variable renewable energy(IRENA et al., 2020).
   - Cooking: Cooking has a high share of building energy use in the global south, largely due to the low efficiency and the use of the traditional use of solid biomass(Cao et al., 2016). Clean and low carbon cooking can be realized through efficient electric cooking (based on renewable electricity) and the use of modern bioenergy, such as improved biomass cookstoves and biosourced butane and propane (bioLPG) based on municipal solid waste other sustainable biomass feedstock(IEA, 2021e).
3) Energy efficient appliances and lighting: Ownership of appliances is expecting to increase rapidly in developing economies. Ensuring best available energy efficient appliances to be used in these countries and only light-emitting diode (LED) lamps to be sold in the middle term is crucial for reducing building electricity demand and net zero emissions of the building sector (IEA, 2021e).
4) Minimize embodied carbon of building materials: Embodied energy and emissions in building materials will play an increasingly important role when buildings become more efficient(Ürge-Vorsatz et al., 2020). Embodied emissions can be reduced by using low-carbon materials, re-using building materials, and extending lifetime of building components(Churkina et al., 2020).
5) Sufficiency measures: these measures avoid the demand of energy and materials and thus tackle the causes of GHG emissions, but also make it easier to provide basic needs to all, through “optimizing the use of buildings, repurposing unused existing buildings, prioritizing multi-family homes over single-family buildings, and adjusting the size of buildings” (Saheb, 2021).

3 Positive SDGs as enablers for building decarbonisation

It has been increasingly acknowledged that building mitigation measures have multiple benefits (co-benefits), which are aligned with SDGs (Thema et al., 2019; Bleyl et al., 2019; Ürge-Vorsatz et al., 2016). Table 1 shows the above-mentioned mitigation strategies could direct be linked to 12 SDGs, which is primarily based on the review in (Pathak et al., 2022). The co-benefits (green texts) could potentially enable mitigation in the building sector(ibid.). On the other hand, building decarbonization could also potentially create negative impacts on SDGs (red texts), e.g., distributional effects and inequality among different income groups, conflicting land use for food production.

Table 1 Building decarbonisation strategies and their interactions with SDGs

SDGs	Decarbonisation Strategy 1: Sufficiency	Decarbonisation Strategy 2: Radically enhance the energy performance of buildings	Decarbonisation Strategy 3: The shift from fossil-fuel-based and low efficient to low carbon space heating and cooling		Decarbonisation Strategy 4: Minimise embodied carbon of building materials
			Space Heating	Space Cooling	
SDG1: No poverty	Access to space heating and cooling will largely help alleviate poverty in developing countries, leading to increased productivity and productive time for new activities (Creutzig et al., 2020 in Pathak et al., 2022)	• Energy efficiency measures result in reduced energy expenditures for households and thus help to alleviate poverty; • Distributional costs of some mitigation policies promoting energy efficiency and renewable, e.g., roof PV, may reduce the disposable income of poor households (McInnes, 2017; Neuhoff et al., n.d.).	Impacts related to access to space heating and cooling	Impacts related to access to space heating and cooling	

SDG2: Zero hunger	Access to clean cooking could provide better food security in developing countries. However, irregular and inappropriate use may reduce its positive impacts (Aung et al., 2016; Climate ADAPT, 2019; Patange et al., 2015; Wathore et al., 2017 in Pathak et al., 2022).	• Energy efficiency measures result in saved energy expenditures, which can be spent on food; • Green roofs may be used for food production	Using biomass for heating and cooking may reduce the available land for food production.		
SDG3: Good health and well-being	Access to space heating and cooling is vital for health due to reduced exposure to heat and cold (Creutzig et al., 2020) in Pathak et al., 2022).	• Improved indoor temperature and thermal comfort due to the improved building envelop and adequate ventilation could a) reduce winter mortality and morbidity rates due to respiratory and cardiovascular diseases, arthritic and rheumatic illnesses, asthma, etc. (Camprubí et al., 2016; Wilson et al., 2016; Thema et al. 2017 in Pathak et al., 2022)., in particular, for low-income, energy-poor households (Thomson et	• Clean heating and cooking can reduce a) indoor air pollution and thus adverse health impacts on households; b) reduce fossil fuel use for heating and cooking and thus improve outdoor air quality. It then contributes to avoiding premature mortality and reduces morbidity	• Improved thermal comfort: Where electricity access is constrained, energy efficient cooling solutions enable a) household access to cooling; b) cooling of health centres and can help them provide health services at lower costs (SEforALL, 2022).	

		al., 2017b; Nunes 2019 in Pathak et al., 2022); b) improve mental health caused by chronic discomfort and high energy bills Howden-Chapman et al. 2012; Payne et al., 2015; Wilson et al. 2016 in Pathak et al., 2022). building a decarbonisation strategy which targets energy-poor households can alleviate energy poverty European Commission 2016 in (Pathak et al., 2022).	(e.g. lung cancers, ischemic heart diseases, hospital admissions, asthma exacerbations, respiratory symptoms, etc.) Karlsson et al. 2020; Balaban and 22 Puppim de Oliveira 2017; MacNaughton et al. 2018; Levy et al. 2016 in Pathak et al., 2022.		
SDG4: Quality education	Access to heating and cooling can mitigate the negative effect on productivity and learning outcomes imposed by cold and heat (Creutzig et al., 2020; McCollum et al., n.d.)	• Improved building envelop result in reduced noise levels, which could enhance academic performance in schools (Kockat et al., 2018 inPathak et al., 2022) • Improved energy efficiency and thus thermal comfort and indoor environment at home can potentially reduce school absenteeism Thema et al. 2017; Niemelä et al. 2017; Mofidi and Akbari, 2017 in Pathak et al., 2022).			

SDG 5: Gender equality	Women spend significantly more time in indoor households than men. Thus, heat-related impacts on indoor households are burdened mainly by women. Thermal comfort and indoor environment improvement due to building energy efficiency and access to low carbon heating and cooling can positively impact women.				
			Clean heating and cooking can reduce the time that women spend collecting fuel and thus increase other activities (Jeuland et al., 2018 in Pathak et al., 2022)	Gender and health: Pregnant women can tolerate heat stress less during pregnancy. Extreme heat without cooling access could increase the risk of harm to the fetus. Heat stress has also been associated with temporary infertility, which affects, particularly men (Kockat et al., 2018; Pathak et al., 2022)	
SDG 6: Clean water and sanitation					
SDG 7: Affordable and clean energy	Access to heating and cooling can alleviate energy poverty.	• Improving the energy efficiency of building direct contribute to SDG7.3 achieving energy efficiency improvement.	• Shifting towards renewable-based heating and cooking can accelerate clean energy use and clean fuels for cooking.	• (Super)Energy efficient appliance, including ACs, is a crucial component to achieving energy efficiency improvement; • Shifting towards renewable-based cooling solutions could accelerate clean energy use (Creutzig et al., 2020; UN, 2021);	

SDG 8: Decent work and economic growth	Access to heating and cooling can reduce the negative health impacts of heat on productivity.	• improved building envelop with adequate ventilation in residential buildings can increase active time for productive work due to reduced sick days (Bleyl et al., 2019; Thema et al., 2017 in Pathak et al., 2022) • Green buildings have neutral to positive impacts on employees' work performance (Thatcher & Milner, 2016; Candido et al., 2019; Kozusznik et al., 2019; Bleyl et al., 2019 in Pathak et al., 2022) • Improved building envelop result in reduced noise levels, which could enhance productivity in office buildings (Kockat et al., 2018) • Jobs can be created from investment in building retrofits or the construction of new energy efficient buildings(International Energy Agency, 2020 in Pathak et al., 2022). estimated 9-30 jobs generated for every million dollars of investment.	Job creation from investment in building retrofits or in construction also includes upgrades of heating and cooling systems.	Using sustainable building materials could create new supply chains, potentially resulting in job opportunities and other social benefits to local communities (Hashemi et al., 2015; Cheong C and Storey D 2019 in (Pathak et al., 2022).

<table>
<tr><td rowspan="2">SDG 9: Industry, innovation and infrastructure</td><td colspan="4">Reduced energy demand due to energy efficiency measures and increasing onsite renewable use can lead to the early retirement of fossil energy infrastructure.</td><td></td></tr>
<tr><td></td><td colspan="3">Developing zero-energy or positive energy buildings and highly energy efficient ACs can foster innovations.</td><td></td></tr>
<tr><td rowspan="2">SDG 10: Reduce inequality within and among countries</td><td></td><td>Enhanced thermal comfort and indoor environment due to building energy efficiency measures could have positive health impacts on women and children, thus enhance education and the development of productive activities

Distributional costs of some mitigation policies promoting energy efficiency and renewable, e.g., roof PV, may reduce the disposable income of the poor households and increase inequalities</td><td>Access to low carbon heating and cooking could save

substantial time for women and children, thus enhancing education and the development of productive activities (Pathak et al., 2022)</td><td>A significant amount of funds have been provided by developed economies to developing countries for sustainable cooling (Creutzig et al., 2020)</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Electrification of heating and active cooling could increase electricity demand and thus energy costs, which further increase the economic burden of the poor (Savage et al., 2022).</td><td></td></tr>
<tr><td rowspan="2">SDG 11: Sustainable cities and communities</td><td></td><td colspan="3">Enhancing thermal comfort through building envelopment improvement and access to low carbon heating/cooling is necessary for safe, resilient, and sustainable cities.</td><td></td></tr>
<tr><td colspan="4">Sufficiency and building energy efficiency measures that reduce fossil fuel demand for onsite or centralised energy generation and shifting towards renewable-based heating and cooking can improve city air quality.</td><td>It contributes to 11.c.1 Sustainable, resilient</td></tr>
</table>

					and resource efficient buildings utilising local materials
SDG12: Responsible consumption and production	• Measures to promote sufficiency, energy efficient building construction/renovations, as well as low carbon heating and cooling reduce natural resource consumption (fossil fuels, metal ores, minerals) associated with final energy consumption (Thema et al. 2017 in Pathak et al., 2022) • Measures to encourage behaviour change of building users towards energy sufficiency and efficiency promote a universal understanding of sustainable lifestyles; • Measures to promote energy efficient building construction/renovations and low carbon heating and cooling in the public sector contribute to sustainable public procurement practices.				Overall: Sustainable consumption and production include promoting resource efficiency. More specifically, it contributes to Target 12.2: Sustainable management and use of natural resources. Target 12.5: Substantially reduce waste generation
SDG13: Climate action	Strategies to enhance sufficiency, building energy efficiency and deploying low carbon heating and cooling will reduce primary energy consumption and thus GHG emissions.				
		Energy efficient building design (e.g., the building aspect ratio, orientation) and building envelope (including applying more reflective white coating), a green roof can reduce the impacts of excess heat and reduce		• Using ultra-low global warming potential refrigerants in space cooling is also key for climate mitigation. • Energy efficient cooling can mitigate potential of increased humidity caused by	

		high cooling demand. These measures strengthen resilience and adaptive capacity to climate-related disasters (Climate ADAPT, 2019; GABC, 2021).		climate change while keeping cooling energy demand low, which strengthens resilience and adaptive capacity to climate-related disasters(Climate ADAPT, 2019; GABC, 2021)	
SDG 14: Life below water					
SDG 15: Life on land					
SDG 16: Peace, justice and strong institutions					
SDG 17: Partnerships for the goals					

4 Synthesis of main barriers to sectoral decarbonization

To accelerate the sector's decarbonisation, a number of barriers still need to be addressed. Within the NDCASPECTS project, we focus on the building operational phase, i.e., the first three strategies. This section summarises the significant barriers to implementing these three strategies.

Political factors represent a crucial barrier. These are overarching barriers of lacking clear vision and signals for building decarbonisation. First, decarbonising the building sector requires long-term commitment, unlike short-term election cycles in many countries (UNEP, 2020). Second, there is often an absence of clear policy signals and incentives for different actors on the value chain to be engaged and invest in building energy efficiency(IEA, 2021f).It is challenging for many governments to develop an ambitious and comprehensive long-term roadmap to outline the building sector decarbonisation pathway (Gaur et al., 2021; Global ABC et al., 2020). Besides, in 2020, still about two-thirds of countries lacked mandatory building energy codes(IEA, 2021b). Although more than 80 countries already have introduced minimum energy performance standards (MEPS) for air conditioners (ACs), MEPS vary significantly across the countries and are weakest or even absent in the regions where rapid growth of AC is expected (IEA, 2020). Countries where ownership levels are currently low but are expected to rise still do not have appliance MEPs (IEA, 2021i). On top of that, subsidies on fossil fuels and fossil boilers have significantly delayed the transition towards renewable-based heating and cooling (IRENA et al., 2020). In many countries, the installation of fossil-fuel heating in new buildings and replacement in existing buildings are still permitted (Lowes et al., 2022). In Europe, millions of subsidies are still paid for new gas boilers (Coolproducts, 2021). Third, governments are themselves owners of public buildings. Thus, they could make these buildings highly energy efficient and equipped with clean and efficient heating and cooling solutions and thus create demand for these options. However, governments often lack the required technical knowledge to make informed decisions and have limited financing to invest in these options(Herrando et al., 2022). On top of that, governments' public budgeting rules do not create incentives for specific authorities or departments to invest in energy efficiency as they may not be able to retain the monetary savings from energy efficient measures, and resulted saving may also reduce their operational budget (Gynther, 2016).

The building sector is characterised by its diverse types, complex value chains dominated by small to medium enterprises, and fragmented governance. For example, the governance of building performance is often the responsibility of multiple jurisdictions, from national to local government. Ministries responsible for buildings often do not have jurisdiction over climate change policies and the environment (UNEP, 2018).

In addition, there are economic and financial barriers. Energy efficient building envelops, heat pumps and super-efficient ACs, and clean cooking are often associated with higher upfront costs and longer payback time than conventional ones (Cohn & Esram, 2022; IEA, 2020; Ürge-Vorsatz et al., 2020). This has been a significant barrier to their adoption. The cost barrier is aggravated by split incentives, where the investors, who own the tenant-occupied buildings, do not financially benefit from their investment in, e.g. energy retrofits and energy systems such as heat pumps (Höfele & Thomas, 2011) . Depending on pricing mechanisms for electricity and fossil fuels, the operational costs for electrification can also be high. The fact that fossil boilers are financially supported further reduces the economic attractiveness of heat pumps(Lowes et al., 2022). Economic factor also persists as a barrier for suppliers. Besides, electric heating and cooling appliances can provide flexibility to the grid system, increasing its cost-effectiveness (OVOENERGY & Imperial College London, 2018). However, policies and power market in many countries do not incentivise consumers to provide flexibility(Yule-Bennett & Sunderland, 2022).

Transitioning to low carbon products and services is particularly costly for suppliers, considering the prevailing price competition with conventional options (Höfele & Thomas, 2011). Meanwhile, suppliers are often uncertain about the market demand for energy efficiency options (ibid.). On top of cost issues, there is generally a lack of access to affordable finance to invest in building energy efficiency and low carbon heating and cooling options. Many households and companies cannot bear high upfront costs from their resources and access to affordable finance options due to informal and irregular income, high transaction costs and interest rates, taxes and down payment requirements. Capital providers(e.g., banks and institutional investors) are inhibited by a lack of liquid capital markets and lacking policy and governance frameworks (Climate Action Tracker, 2022a). They often lack technical knowledge of building energy efficiency projects and assessments. There is also no supporting energy performance data (G20 EEFTG, 2017). They also perceive high lending and investment risk associated with these projects due to lenders' lack of track records, low collateral asset value, a long project lifetime, and high-performance risks. In addition, individual building projects are relatively small; thus, the transaction costs of assessing each project are high (ibid.). Last but not least, governments, in particular, in developing economies, often lack funding to finance both policies for supporting the implementation of energy efficiency investments and research and development activities as well as demonstration projects (RD&D), such as deep retrofits, net-zero carbon buildings, plus-energy buildings.

Another key barrier is due to the lack of capacity, i.e., the knowledge and skills required on the supplier chain, such as designing (in particular, identifying the best technology mix) and construction of high-energy-performance buildings and designing, installers of low carbon heating and cooling systems, building energy managers, etc. This was revealed as a common barrier that significantly impedes the scaling-up of these building decarbonisation options (UNEP, 2020).

Building decarbonisation also faces technical barriers, ranging from infrastructure (network) and building characteristics (e.g., structure, orientation) to technical processes. For example, a critical barrier to market penetration of decentralised heat pumps is the incumbent heating infrastructure (e.g., the gas grid), which is associated with significant sunk costs invested by gas utility companies(Lowes et al., 2022). The overall physical characteristics of the built environment, e.g. shape, size, density and configuration, can influence energy consumption and implementation of renewable-based heating and cooling (Global ABC et al., 2020; Sheldon et al., 2018). Property owners and users may be discouraged from undertaking deep renovations because of the associated disruptions(Trinomics. et al., 2022). Also, the technology maturity of specific technologies and solutions can impede the uptake of the measures, e.g. solar cooling and zero/plus energy buildings (Sheldon et al., 2018). Beyond the building level, the increasing electrification of heating and cooling will significantly increase electricity demand and peak and thus create challenges in the grid system, particularly the distribution grid(Love et al., 2017).

Availability and access to information about decarbonisation measures impede consumers and investors from adopting these measures(Höfele & Thomas, 2011; Mata et al., 2021, 2022). To make investment decisions, consumers and investors need to know the best energy efficiency that suits their needs, installation and operation complexity, and cost-effectiveness (Mata et al., 2021). Data on energy performance and cost savings after implementing measures are essential, but they are not always available or consistent(Criado-Perez et al., 2020). Although the improved technology enables heat pumps to operate well even in cold regions(Wei et al., 2020), the previous low performance of heat pumps in these regions causes concern among consumers about their reliability.

Social and cultural factors also have a significant impact. In North America and Europe, in combination with information availability, consumers' attitudes and values were identified as one of the most critical factors in improving the building envelope(Mata et al., 2021). Besides, building occupants' behaviour can limit the GHG reduction potentials of building energy performance improvement, e.g., through increasing ownership and use of appliances (IEA, 2019a) and demand for more living space(Bierwirth & Thomas, 2015).

Last but not least, structural factors such as population and economic growth, as well as urbanisation, in particular, in emerging and developing economies, have been driving the increases in floor area expansion and energy demand. These factors may outweigh improvements in energy efficiency (Zhou et al., 2018; IEA, 2021b)

5 Policy instruments for decarbonising the building sector

The previous chapter shows that multiple barriers have impeded building decarbonisation, which a single policy instrument cannot address. Thus, policymakers need to find a balanced policy package (Rogge & Reichardt, 2016; Schmidt & Sewerin, 2019) which combines a broad range of policy instruments that reinforce each other to decarbonise the building sector (Hoefele & Thomas, 2011; Kern et al., 2017; Rosenow et al., 2017). This section summarises how different policy instruments address the depicted barriers and presents selected good practices in different countries.

5.1 Primary functions of different policy instruments

A wide range of policy instruments can overcome the barriers to realising the three decarbonisation strategies. In this project, we categorised policy instruments into the following ten categories based on (bigEE, n.d.-a): governance and planning, regulatory instruments, economic instruments, market-based instruments, information instruments, policies that support capacity building, promoting research and development, demonstration projects (RD&D), leading by examples, and policies promoting business models and financing. Table 2 presents how the primary functions of these policy instruments address each barrier. The description is a shorthand for the complex reality and considers only the primary policy functions.

Table 2 the primary functions of different policy instruments addressing each barrier

Barriers	Primary functions: How policy instruments can address each barrier	
Political	**Governance and planning instruments**	• ***Policy roadmap*** defines clear targets and strategies of building envelop improvements and low carbon heating/cooling, providing a reliable planning framework for market actors and reduce risk for investors • ***Energy efficiency funds***-Dedicated funds by the government or by energy companies obligated through regulation demonstrates political support and creates a stable favourable investment environment; • ***Removing subsidies for fossil fuel***, ***carbon pricing, and energy taxes, levies and surcharges*** on energy carriers reflecting their GHG emissions intensities a) levels the playing field for low carbon heating by increasing the costs of the fossil fuel alternatives; b) provides a long-term vision for building decarbonisation.
	Regulatory instruments	• ***Building energy codes*** makes building energy efficiency and low carbon heating/cooling for buildings as standard, sending a clear signal to market actors; • ***Phasing out fossil fuel boilers*** sends a signal to the market on the exclusion of fossil fuel alternatives in the near- and medium-future.
	Lead by example	It helps to establish a vision of building sector decarbonisation and raise investors' confidence.
Economic and financial	**Governance and planning instruments**	• ***Energy efficiency funds***-Dedicated funds by the government or by energy companies provides stable funding sources to financing the upfront costs of decarbonisation options; • ***Energy Efficiency Obligations*** financing the upfront costs of decarbonisation options

		• ***Pricing mechanisms*** make investments in building energy efficiency and on-site renewable energies more attractive; revenues used to support climate mitigation
	Regulatory instruments	• ***Building energy codes*** address split incentives by requiring a reasonable level of energy efficiency of rental buildings. • ***Rental regulations*** should specify the redistribution of investment cost and energy cost savings.
	Economic instruments	• ***Financial incentives*** overcome higher upfront costs of decarbonisation options and can also address the split incentives by reducing the burden of compliance by landlords. • ***Energy saving auction*** calls for competition among market actors for funding budgets on energy efficiency projects in a most cost-benefit manner.
	Promoting business models& financing	• ***Policies promoting energy services-*** *ESCOs* (Energy Service Companies) finance the decarbonisation measures or help investors to identify and structure funding. • ***Policy promoting OSS***, which gives investors advices for financing. ***Policies supporting innovative financing mechanisms*** overcome higher upfront costs of decarbonisation options.
	Lead by example	Scaling up building decarbonisation options in public buildings helps to increase market penetration and thus reduce market prices for these technologies.
Capacity	**Policies supporting capacity building**	***Training and education*** provide stakeholders with the necessary knowledge and skills ***Certification of qualified actors*** can increase capacity and credibility of working forces
Technical	**Governance and planning instruments**	• ***District energy planning*** takes a systemic approach integrating energy demand (considering energy performance of new buildings and energy retrofits) and supply at district level; renewable-based modern district heating network in place. • Government promotes the development of efficient renewable-based ***district energy networks*** • ***Mandatory planning requirements*** to investors regarding building shape, size, and siting, and integration of low carbon energy supply
	Policies promoting RD&D	***RD&D policies*** foster innovations of design concepts for highly energy efficient buildings and novel heating/cooling technologies, serial building renovations such as Energiesprong
Information	**Promoting business models & financing**	• ***Policies promoting energy services- ESCOs*** can provide property owners information on energy saving potentials and cost-effective holistic solutions of energy renovation including low carbon heating & cooling solution. • ***Policy promoting OSS***, which provide property owners easy access to technical and financial information.
	Information instruments	• ***Building rating and disclosure policies*** enables stakeholders to be informed about on energy use of the building for their purchase and renting;

		• ***General information provision*** raises awareness about decarbonisation options and their cost-effectiveness among key stakeholders***;*** • ***Policies supporting target energy advices*** helps property owners to identify concrete energy saving opportunities and to assess the related costs and benefits

5.2 Governance and Planning instruments

- **Policy roadmap**

Barriers addressed: Political and institutional

A ***policy roadmap*** includes ambitious, achievable targets of energy savings, low carbon heating and cooling, and comprehensive medium- to long-term strategies. It provides a reliable planning framework for market actors and reduces the risk for investors (*bigEE*, n.d. -a).

According to the EU Energy Performance of Building Directive (EPBD), all member states(MSs) must ensure all new buildings are nearly zero-energy by the end of 2020, in which all new public buildings had to be nearly zero-energy from 2019 on. The EU also proposes to move from the current nearly zero-energy buildings to zero-emission buildings by 2030(European Commission, n.d.-d). For heating, e.g., France aims for 38% of total heat consumption based on renewables by 2030, with specific targets for deploying heat pumps (Lowes et al., 2022).

- **Removing subsidies for fossil fuels and fossil boilers**

Barriers addressed: political, economic

Removing subsidies for fossil fuels and fossil boilers is essential for levelling the playing field for renewable-based electrification for upfront and operation costs (IRENA, IEA and REN21, 2020). For example, to achieve its Paris Agreement goal, the EU has committed to phasing out all fossil fuel subsidies by 2025 (Coolproduct, 2020).

- **Energy Efficiency Obligations**
  Barriers addressed: economic, information

Energy Efficiency Obligations (EEOs - also known as Energy Saving Obligations, Energy Efficiency Resource Standards, Energy Efficiency Performance Standards or White Certificates) obligate energy suppliers to carry out measures that deliver energy savings. In return, energy suppliers also have the right to cost recovery for organising and funding energy efficiency programs (*bigEE*, n.d. -a; Rosenow et al., 2019).

To ensure the effectiveness of EEOs, the target should be set clearly beyond business-as-usual. Besides, the cost-recovery mechanism of energy suppliers needs to be clear and transparent. Furthermore, An accepted and accurate yet practical methodology for verifying achieved energy savings is the key to successful implementation (bigEE, n.d. -a).

Through EEO, most successful countries achieve gross energy savings equivalent to around 2 % per year. Usually, these energy savings are cost-effective for consumers and society. (*bigEE*, n.d.-a; Rosenow et al., 2019). If properly designed and combined with other instruments, such obligations can potentially support the deployment of renewable heating by promoting specific technologies such as heat pumps or more efficient use of electricity (Lowes et al., 2020). This policy has been implemented in a number of countries, such as the USA, Europe, Canada, Brazil, Uruguay, China, South Korea, South Africa, etc. (Rosenow et al., 2019). However, this instrument has mainly supported technologies with low capital costs rather than low carbon heating systems. UK's Energy Company Obligation (ECO) is

one example supporting heating, in which utilities fund the installation of heat pumps in households (Ofgem, 2022).

- **Pricing mechanisms**

Barriers addressed: economic

Carbon pricing mechanisms, namely, carbon tax and pricing, reflect externalised carbon costs of fossil fuel and rebalance energy prices in favour of electrification (Lowes, et al.,2022). These mechanisms potentially make investments in building energy efficiency and on-site renewable energies more attractive. The generated revenues can be further used to support climate mitigation, including building energy efficiency and renewable energy, particularly for low-income households living in worst-performing buildings who are negatively affected by carbon pricing (Lowes et al., 2022; Thomas, Sunderland, et al., 2021). It is claimed that explicit linkage between the carbon price and the support on which its revenue will be spent could increase public acceptance of carbon pricing(Thomas, Sunderland, et al., 2021). German government launched a national carbon pricing system for the building sector in 2021. It starts with a fixed price, which will increase annually before allowances are auctioned from 2026 onwards (ICAP, n.d.). Since 2015, the Republic of Korea has also implemented an Emission Trading Scheme, including the building sector (Narassimhan et al., 2018). At the local level, in 2019, New York City Local Law established "Carbon Allowances" for 34 large buildings (Spiegel-Feld, 2019).

Energy taxes, levies and surcharges on energy carriers reflecting the GHG emissions intensities of fossil fuel incentivise the investment in low carbon heating, e.g., supporting lower operational costs for electric heating compared to fossil fuel alternatives. In some countries, such as Finland, taxation on fossil fuels has increased significantly to support the phase-out of fossil boilers (Hannon, 2015).

- **Energy Efficiency Funds**

Barriers addressed: economic, capacity, information

Energy Efficiency Funds are overarching funds and typically include several policy instruments to promote energy efficiency in different sectors, including the building sector. They have been implemented in Europe (e.g., UK and Denmark) and the US (California, Oregon, Connecticut, and Massachusetts) since the 1990s (Odyssee-Mure, n.d.-a).

The supported programmes typically combine information, financial incentives and financing, capacity building, RD&D, etc. The funding for an Energy Efficiency Fund can be provided from the government's budget, which is often subject to political fluctuations. Funding through a special levy, tax, or revenue from emissions allowances is quite common and allows a more stable income than yearly budget allocations. Climate finance (particularly Programmes of Activities – PoA – under the Clean Development Mechanism – CDM and Nationally Appropriate Mitigation Actions – NAMAs) can be used by developing countries and emerging economies to (part-)finance energy efficiency funds (bigEE, n.d.-c).

- **Governance structure**

In addition, the country needs a ***dedicated political body*** (ministry or department) to take political response related to building decarbonisation. The political responsibility may also be legally binding. For example, in Germany, if a sector exceeds its annual GHG emission limit set in the law, the responsible ministry must develop and implement an emergency program to achieve additional reductions to the same amount as the overshoot.

Furthermore, ***coordination mechanisms*** among ministries, among national, subnational and local governments, and the involvement of various stakeholder groups, are essential for effective implementation of the roadmap(IEA, 2022b).

5.3 Regulatory instruments

- **Building energy codes**

Barriers addressed: political and institutional, information, economic (split incentives)

Building energy codes sets an upper limit for the allowed energy consumption of a building and thus exclude at least the most inefficient building concepts and technologies from the market (*bigEE*, n.d.-a). They are cost-effective for energy savings and CO_2 emission reductions in buildings (IEA, 2021b). Besides energy efficiency, some governments also include the share of renewables and embodied emissions (Schwarz et al., 2020).

As of November 2021, 80 countries have implemented mandatory or voluntary building energy codes at the national or subnational level, of which 43 countries have national mandatory codes for residential and non-residential buildings(UNEP, 2021).

Building energy codes should account for technology progress and thus be tightened over time until net zero is reached. In China, the energy savings level in its building energy efficiency standards has risen continuously since its implementation in the 1970s (IEA, 2021b). Besides, the tightening must be fast enough for PA compatibility (CAT, 2022a). Furthermore, the tightening can be embedded in A long-term roadmap of sectoral decarbonisation to provide a planning framework for market actors.

In countries with high existing building stock, energy performance requirements should also be considered for existing buildings, at least if they undergo a major renovation (*bigEE*, n.d.-a). In the EU, for example, minimum performance requirements at cost-optimal levels are set for buildings undergoing a major renovation. Besides, building energy codes for existing buildings can also address split incentives as it can require the landlords to ensure a reasonable level of energy efficiency in their rental buildings. To reduce the burden of compliance by landlords, policies that address upfront costs need to be in place. Besides, rental regulations also need to be revised, which specifies the redistribution of investment cost and energy cost savings. For example, green leases, which allow landlords to increase the rent to finance energy efficiency measures through a clause or separate agreement with tenants, have been increasingly deployed in large commercial buildings in the U.S. and Australia (Castellazzi et al., 2017). The rent increase is typically calculated based on predicted energy savings. However, to shield tenants from technical risks of underperformance, for example, in New York City, landlords can only pass on up to 80% of predicted savings to tenants(Castellazzi et al., 2017).

Furthermore, regulations can be developed to restrict different fossil fuels and their heating equipment or to obligate using heat pumps. These can also be relatively easy to introduce in building energy codes, particularly for new buildings (Lowes et al., 2020, 2022). Several local governments in the U.S. have revised or announced their intention to revise building energy codes to restrict fossil fuel heating. In November 2021, California passed the first building energy code that establishes heat pumps as a baseline technology, which will take effect in 2023 (NRDC, 2021). In April 2022, Washington State voted to include electrification in the statewide building code for new buildings (DiChristopher, 2022). In France, its new building energy code will limit the emissions intensity of space heating and cooling systems so that fossil fuel technologies cannot be used (Ministry of Ecological Transition, 2021).

- **Phasing out fossil fuel boilers**

Barriers addressed: political and institutional information

Beyond building energy codes, regulations can also prohibit the use of fossil fuels and fossil fuel boilers by a predefined date

It can be introduced step-wise, e.g., first phasing out fossil fuels in new buildings and then in existing buildings. However, partial phase-out of fossil boilers, e.g. allowing hybrid solutions, could create lock-in effects of fossil-fuel heating (Braungardt et al., 2021).

In several European countries and regions (e.g., Austria, Denmark, Norway, the Netherlands, France, and the Flemish region of Belgium), different fossil fuels and their heating equipment are restricted for new and existing buildings. In Denmark, buildings located in district heating (DH) areas can only be heated by DH or by renewable sources (Braungardt et al., 2021).

- **Product-specific Minimum Energy Performance Standards (MEPSs)**

Barriers addressed: political and institutional, economic, information

Product-specific Minimum Energy Performance Standards (MEPSs), which are continuously strengthened towards the best available technologies, prove to be the most cost-effective policy measure for boosting the efficiency of appliances, including heating and cooling equipment (IEA, 2018; Ürge-Vorsatz et al., 2007). More than 80 countries already have mandatory and voluntary MEPSs for air conditioners (ACs), and over 20 countries are developing their MEPS (IEA, 2021b). However, MEPSs differ significantly across countries: they are generally most stringent in developed countries and are weakest or even absent in hot or humid countries with rapidly growing demand for ACs (IEA, 2018).

5.4 Economic instruments

- **Financial incentives**

Barriers addressed: economic (including split incentives)

Financial incentives may be required to overcome higher upfront costs of investment in heat pumps or super-efficient cooling, nearly zero-energy new buildings and deep renovation, and transitioning towards relevant technologies/products for suppliers. It can take different forms, from grants, soft loans, and rebates for purchasing products to tax incentives, targeting different target groups (Lowes et al., 2020). These measures also send a signal of the potential development of the sector to suppliers, thus reducing their uncertainty (CAT, 2022a). This also requires continuity and stability of financial incentive programs. To encourage investment in measures beyond business-as-usual, the financial incentives can be linked to the energy efficiency level, i.e., the better the performance, the higher the incentive should be (bigEE, n.d.-a).

Grants are direct funding by governments, in particular, to support activities which are not economically viable yet and thus to incentivise first-movers' investments (Bertoldi et al., 2019). In Germany, the Federal Funding for Efficient Buildings was launched in 2021 to provide funding for investing in building decarbonisation measures. It has three sub-programs: residential buildings, non-residential buildings, and individual measures. For example, under the "Individual Measures (BEG EM)", 35% of the investment costs of heat pumps for modernisation is funded (e.g., replacing gas heating or an old heat pump with a new heat pump). For replacing the old oil heater with a heat pump, the subsidy amounts to 45% of the investment costs(BAFA, n.d.). The UK Government officially launched the Boiler Upgrade Scheme in 2022, offering upfront grants of up to £6,000 for installing heat pumps in buildings(GOV.UK, 2020). To address split incentives, from 2014 to 2017, the Netherlands government

made available a €400 million subsidy for landlords of rental social houses to invest in energy efficiency (Castellazzi et al., 2017).

Soft loans with below-market interest rates are available to promote new construction of highly energy efficient buildings and deep innovation, including the installation of low carbon heating and cooling (Kern et al., 2017). Governments can provide through public banks (e.g. soft loans program by German development bank KfW) or collaboration with private financial institutions (Bertoldi, Economidou, et al., 2021). Compared to grants, governments bear a lower burden.

A rebate program offers consumers a small discount for highly energy-efficient cooling appliances. It can enhance consumers' recognition of highly efficient cooling and incentivise them to purchase the products.

Tax credits, in which a certain percentage of the investment cost of selected technologies can be deducted from income taxes, have also been implemented to promote energy renovation in several countries. In Italy, Europe's second-highest heat pump sales, homeowners are entitled to a tax credit of up to 110% for home energy upgrades, including heat pump purchases (European Commission, 2021a). Another tax incentive links the level of property tax to the building energy performance. The higher the energy performance is, the lower the property tax. It has been implemented in the region of Flanders in Belgium since 2013. Property tax can be reduced by 20-100% for five to ten years (CAT, 2022a). From 2014 to 2017, the UK government dedicated £35 million for a tax break to incentivise residential landlords to invest in energy efficiency measures (Castellazzi et al., 2017).

5.5 Policies promoting business models and financing

- **Policies promoting energy services**

Barriers addressed: economic, technical, information

Energy service companies (ESCOs) can be important in building energy renovation. They can provide building owners with holistic solutions for energy renovation, including low carbon heating and cooling systems. Their services range from performing retrofits and installing heating and cooling as well as on-site renewables, mobilising financing or investment, and managing projects, to operation and maintenance. There are two project types when providing Energy Performance Contracting: a) guaranteed-savings: the ESCO designs and implements the project and guarantees the energy savings, thus protecting the client from technical and implementation risk. ESCOs are subject to penalty fees if energy savings are less than the guaranteed level; b) shared-savings: ESCOs finances and implement the project. In return, they receive a recurring fee from the client for a defined period (Boza-Kiss et al., 2017).

Major policies that promote ESCOs include:

- Energy efficient public procurement: A favourable framework condition for ESCOs' involvement in public procurement should be created (Marino et al. 2010). The public sector can lead by example by using energy services for deep renovation of public buildings (Boza-Kiss et al., 2017).
- Financial incentives: Where financial incentives for investment in building energy efficiency exist, they should also be open for ESCO projects. ESCOs should be eligible to receive grants or other incentives.

- Standards and certification: Establishing standardisation and a certification scheme can significantly reduce transaction costs for energy service provision (Suerkemper & Wolfgang, 2010). For example, in Europe, to support energy performance contracting in the public sector, MSs must provide model contracts (Boza-Kiss et al., 2017). Certifying ESCOs also ensures the quality of the providers and can increase the confidence of investors and financial institutions (bigEE, n.d.-e). For instance, in Slovakia, EPC can only be provided by those with a certificate for providing Guaranteed Energy Services or an energy auditor (Boza-Kiss et al., 2017).
- Financing: Policies that facilitate their access to financing are crucial for energy efficiency service market development. These include policies or measures such as a loan guarantee by the government, special-purpose credit lines/revolving funds, and engaging financial institutions (Marino et al., 2010). Also, financing mechanisms, such as revolving funds for energy efficiency, can be developed to enable the EES provision in sectors characterised by high transaction costs, such as the residential sector (Szomolanyiova & Vladimir, 2012).
- Information provision: Targeted information about ESCOs, their business models, and the benefits of using energy services should be provided to key stakeholders, such as investors and financial institutions. For investors, it is also important to provide information, e.g. an online database, about qualified ESCOs (*bigEE*, n.d.-a).
- Capacity building: Training can be provided for ESCOs to strengthen their technical and management capacity (Marino et al., 2010). Financial institutions also need to be trained to understand ESCOs' business models and how to assess their projects and associated risks when providing them loans.
- Policies to support intermediaries between ESCOs and key stakeholders: Evidence shows that intermediaries contribute positively to ESCO market development by supporting project development, bridging customers and ESCOs, and encouraging competition between ESCOs. These intermediaries can also lower the transaction costs of energy efficiency services (Bleyl et al., 2013; Nolden et al., 2016) (see below).

- **Policies promoting intermediaries / One-stop-shops (OSS)**

Barriers addressed: economic, technical, information

One-stop shop (OSS) is a collective term for services offering integrated solutions for energy renovation, which aims to guide property owners throughout the renovation journey. It can provide property owners easy access to information, such as energy renovation measures and their benefits (e.g., energy and cost savings), technical recommendations, financial options, and qualified service providers. It supports renovation implementation by structuring and even providing financing, integrating services from different suppliers, and providing guidelines and ready-to-use templates for contracting. Its services can also include a quality assurance by offering certification for the contractors and supporting the following-up process, e.g., developing guidelines on proper follow-up checks. In Europe, OSS is a part of the Energy Performance of Buildings Directive (EPBD) as part of the Directive 2018/844/EU (Bertoldi, Boza-Kiss, et al., 2021). Over 60 one-stop-shop models have been set up across the EU in the last decade (Boza-Kiss et al., 2021).

To facilitate the deployment of OSS, first of all, OSS needs to be recognised in the legal framework. Besides, the government can also support OSS pilots through its research and innovation funding program. Furthermore, financial support is needed for setting up OSSs. At the local level, the government can operate OSS. Around 40% of OSS in Europe are operated by local governments and are closely linked to municipal renovation strategy (Boza-Kiss et al., 2021). Accordingly, capacities at the local

level, such as communication, project management, monitoring and verification, and financing, need to be built up (Volt & McGinley, 2021).

5.6 Information instruments

- **Building rating and disclosure policies**

Barriers addressed: information

Building rating and disclosure inform building owners and occupants regarding the energy use of the building. It could also create demand for energy efficiency measures by setting energy performance as a criterion for purchasing, rental or investment and by providing recommendations for the cost-effective improvement of energy performance (*bigEE*, n.d.-a; BPIE, 2014; Subramanian et al., 2022).

In Europe, energy performance certification (EPCs) is mandatory, which aims to inform prospective buyers or tenants about the energy performance of the buildings compared to that of a similar building (Castellazzi et al., 2017). EPC is an important component of the Energy Performance of Buildings Directive (EPBD). The EPBD proposal specifies measures to make EPC much clearer, more reliable and visible, with easy-to-understand information on energy performance and other key indicators for stakeholders. Besides, it also includes a template for EPCs with a minimum number of common indicators on energy and GHG emissions, complemented with a number of voluntary ones, such as on charging points, indoor air quality and Global Warming Potential based on the building's life-cycle carbon emissions. Last but not least, it specifies common requirements for the databases and the provision of public access to databases on building energy performance. This will improve the information quality and support public authorities and financial institutions in decision-making (European Commission, 2021c).

- **Energy labelling schemes of products**

Barriers addressed: information

Energy labelling schemes for appliances, which inform consumers about the energy consumption of the products, aim to pull the market towards higher efficiency (*bigEE*, n.d-a.). The labels can also provide a basis for incentive programs (IEA, 2022b). This instrument has been successfully implemented worldwide in two forms:

- Mandatory labelling is often implemented together with MEPS: OECD countries, China and many developing countries such as Ghana, Kenya, India, and South Africa) (Chunekar, 2014; Diawuo et al., 2018).
- Voluntary labelling: Energy Star program in the US (Ohler et al., 2020).

There are typically two types of labels: a) categorical labels give appliance models distinct rankings or scores based on their energy use or efficiency, such as EU's energy label; b) continuous scales specify the high and low ends of energy use or efficiency among all appliance and place each appliance in the appropriate place along the continuum, such as the U.S. EnergyGuide program. The former has proven to be better understood and more motivating than the latter (Subramanian, Bastian, Jennings, et al., 2022).

- **Target energy advice**

Barriers addressed: information

For both new buildings and existing buildings, individual targeted advice helps building owners to identify concrete energy saving opportunities and to assess the related costs and benefits. Successful energy advice programs can trigger a high and cost-effective investment in building energy efficiency and enhance the effectiveness of other policies. Thus, policy should ensure free basic advice is provided and consider financial incentives for comprehensive energy audits and consultancy to stimulate demand for them. Policies should also support advice to investors to find qualified professionals and requirements of financial incentives and financing programs. An effective advice program should include marketing and outreach activities to make target groups aware of the program. A certification scheme for energy advisors and consultants is essential to ensure the quality of advice.

In Germany, building owners can receive grants that cover 80% of the eligible costs for energy advice, in which they gain a detailed overview of the energy performance of their building and step-by-step recommendations for energy renovation (so-called Individual Renovation Roadmap (iSFP)). The iSFP contains both short and long-term measures and strengthens the interlinkages between these measures. Yet customers are free to choose the specific measures. When applying for the KfW's soft loan, the building owners need to submit a confirmation from the auditor that they implement the respective measures based on the iSFP. For every iSFP measure, they can receive an extra 5% of repayment grant(KfW, n.d.).

- **Provision of information**

Barriers addressed: information, social and cultural

Provision of information (e.g. information campaigns, provision of communication materials, tools for demonstrating cost-effectiveness, online databases with information on most efficient products, independent performance data, and suppliers, etc.) is a common policy instrument to raise awareness among key stakeholders (*bigEE*, n.d.-a; Hanna et al., 2016). An effective approach is to integrate the social norm at the core of the information and awareness measures, for example, facilitating more affective and experiential engagement (Rivas et al., 2016).

These promotion activities are carried out not only by the government but also by many other actors. As a policy instrument, it is often part of a policy program, including different policy instruments. For example, the information campaign in the Swiss heat pump promotion program disseminated information about heat pumps in each Swiss region through community events involving different actors, e.g., municipal utilities, installers and manufacturers, and local communities. The overall program has led to the rapid adoption of heat pumps in Switzerland (Hanna et al., 2016).

5.7 Policies supporting capacity building

- **Training and education**

Barriers addressed: technical

Training and education aim to provide workforce with the necessary knowledge and skills for designing, building, retrofitting, operating, monitoring and assessing energy efficient buildings and low carbon heating and cooling system. Evidence shows that training can have a very high leverage effect and can thus be very cost-effective, due to its creation of new business opportunities (European Commission, 2011).

Many countries have already started to adapt their education and training systems to the current demand for building energy efficiency. Activities include the creation of new curricular and adaptation of existing ones in lifelong training programs, offering electives and postgraduate degrees in universities/colleges, short-term training programs outside workplace, etc. (*bigEE*, n.d.-a). Governments play a key role in setting up formal education and training systems or new training-related institutions. However, since the public system may be slow in responding to the market demand, the involvement of social partners, such as industry associations and workers' organizations, or public-and-private initiatives, to provide more flexible and short-term specialized training is essential (ILO, 2011).

- **Certification of qualified actors**

Barriers addressed: technical

Certification of qualified actors is key to ensuring accurate, optimal, and safe services and to enhancing confidence of investors/users on the services delivered (bigEE, n.d.-d). Certification of trained workforce can increase their credibility (*bigEE*, n.d.-a). In Europe, the Renewable Energy Directive (RED) requires installers to have a specific certification for installing heat pump technologies (ehi, 2021). At the national level, qualification schemes for installers of small-scale renewable system, including heat pumps, are in place in different countries (RESEU, 2020). In France already 25% of the installers are qualified to work with heat pump technologies (ehi, 2021).

Such certification can be managed by different actors, including both government and private certification bodies. For instance, European Heat Pump Association establishes the EUCERT program, which aims at training and educating heat pump installers throughout Europe (EHPA, n.d.). However, it is important that governments specify which certification is necessary for which services (e.g., RED for heat pump installers, special certification for issuing an Energy Performance Certificate or calculating the energy performance vs. the requirements of building energy codes). Besides, governments should also ensure that an independent organization regulates the market of private certification bodies. For example, in the UK, Office of Qualifications and Examinations Regulation (Ofqual) is responsible for maintaining standards, recognizing private certification bodies, and monitoring activities (GOV.UK, n.d.).

5.8 Promoting research and development, demonstration projects (RD&D)

Barriers addressed: technical

Policies that promote RD&D can foster innovations of design concepts for highly energy efficient buildings, both in new build and retrofit, and the associated technologies. It will contribute to mid-term and longer-term policy goals and help ensure these concepts and technologies are ready for commercialisation in time (*bigEE*, n.d. -a).

In Germany, the Federal Government funds research, development, and demonstration of energy-efficient buildings and districts within the Energiewendebauen research initiative. Among others, funding is available for energy-optimized and net-zero buildings, district energy transition and the supply of heating and cooling, thermal energy storage, etc. It also finances the Energiewendebauen research network(energiewendebauen, n.d.). Furthermore, innovative technology combined with business

models such as serial building renovations (Energiesprong) has been supported since May 2021 (Deutsche Energie-Agentur, 2021).

5.9 Lead by examples

Barriers addressed: technical

The public sector's "lead by examples" can create the first markets for highly energy efficient buildings and low carbon heating and cooling technologies. In addition to saving energy and reducing public expenditure, such programs also raise awareness and investor confidence. The resulting demand volumes can increase market penetration and reduce market prices for these technologies. This, in turn, will lead to these technologies being used more often and eventually becoming the default technology in new construction and retrofit. (bigEE, n.d. -a).

For example, in 1993, a public procurement program was launched in Sweden to stimulate the development and commercialisation of heat pumps. In combination with subsidies, information campaigns, and evaluations of heat pump installation, sales of heat pumps had increased by an average of 35% annually until 2006 (Kiss et al., 2012).

The City of Frankfurt am Main established the Passive House Standard for Municipally Owned and Municipally Used Buildings at the municipal level in 2007. Since then, all municipal buildings must be passive houses (PH) with annual heating energy demand not higher than 15 kWh/m^2 (*bigEE*, n.d.-a).

6 Country studies

This chapter presents how the following ten countries have addressed the various barriers to building decarbonisation with various policy instruments: the USA, the EU, China, India, Indonesia, South Africa, Japan, Turkey, Mexico, and Vietnam. The chapter starts by describing the big picture of the building sector in these countries: energy consumption and CO2 emissions. Then we deep dive into each country to analyse the barriers and map the ***current*** policies and measures.

We limit ourselves to three building decarbonisation strategies: improving building envelope performance, shifting to low carbon heating, cooling, and cooking (including interaction with the power system)[1], and energy efficient appliances and lighting. This report does not investigate the strategies of sufficiency and minimising embodied carbon of building materials as they reveal different approaches. Sufficiency has different interpretations between developed and developing economies.

6.1 Background

As of 2020, buildings consume at least 20% of the total final energy consumption (TFC) in most countries. India's building sector has the highest share, with over 48% of TFC. It is followed by the EU27 (almost 42%), Japan (34%), and Turkey (34%). In most countries, the share of residential energy consumption is much higher that of the than services sector.

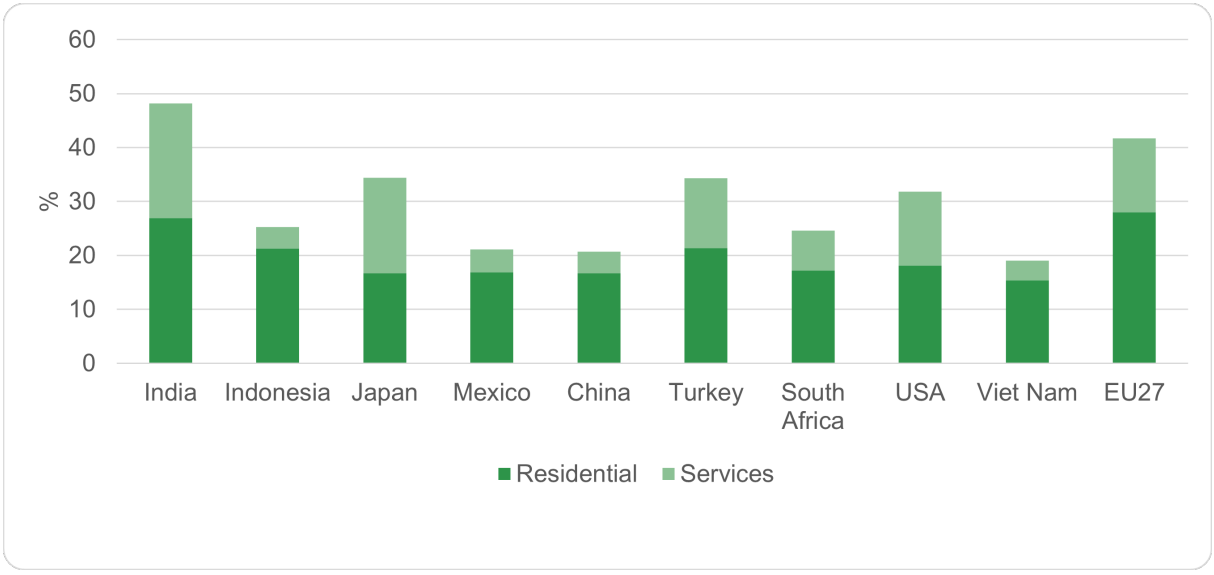

Figure 1 The share of building energy consumption in total final consumption (2020)

[1] Cooking is only included if it is essential for energy end use in the building sector of a specific country.

Source of data for all countries except the EU: Table: Share of total final consumption (TFC) by sector on country pages of the IEA (IEA, 2023). CO2 emissions are from fuel combustion only and without the CO2 emission factors from electricity generation.

Source of data for the EU: Dataset from Eurostat: Final energy consumption by sector (Eurostat, 2023d)

Direct CO2 emissions of the building sector show a different picture across the countries(Figure 2). Turkey's building sector has the highest share (almost 17%), followed by the EU (more than 14%) and the US (12%). This can partly be explained by the fuels used in the building sector (Figure 3). In all these countries, fossil fuel direct uses are predominant in the fuel mix for buildings. India's building sector has been largely fuelled by renewables, leading to lower CO2 emissions. In terms of the share between the residential and service sectors, CO2 emissions show similar trends as TFC, except in India, where the service sector has a much lower percentage. The possible reasons are the much higher share of electricity (25.5%) and oil consumption(15.5%) in the residential sector than those in service sector (7.5% electricity; 1.1% oil).

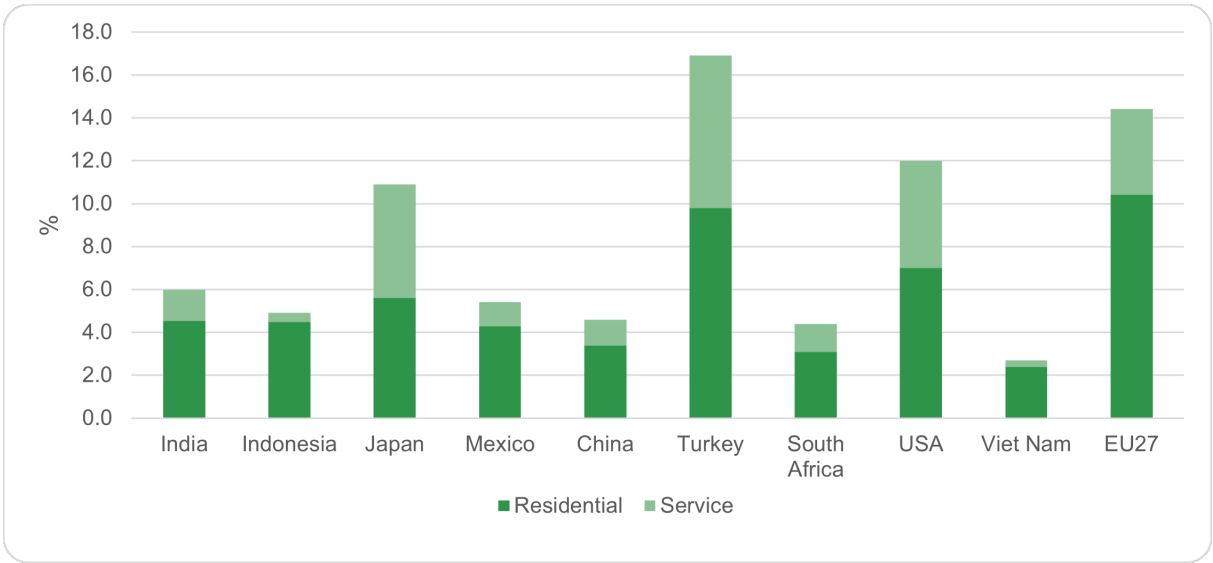

Figure 2 The share of building CO2 emissions (2020)

Source of data for all countries except the EU: Table: CO2 emissions by sector on country pages of the IEA (IEA, 2023)

Source of data for the EU: Dataset from Eurostat: Final energy consumption by sector (Eurostat, 2023e)

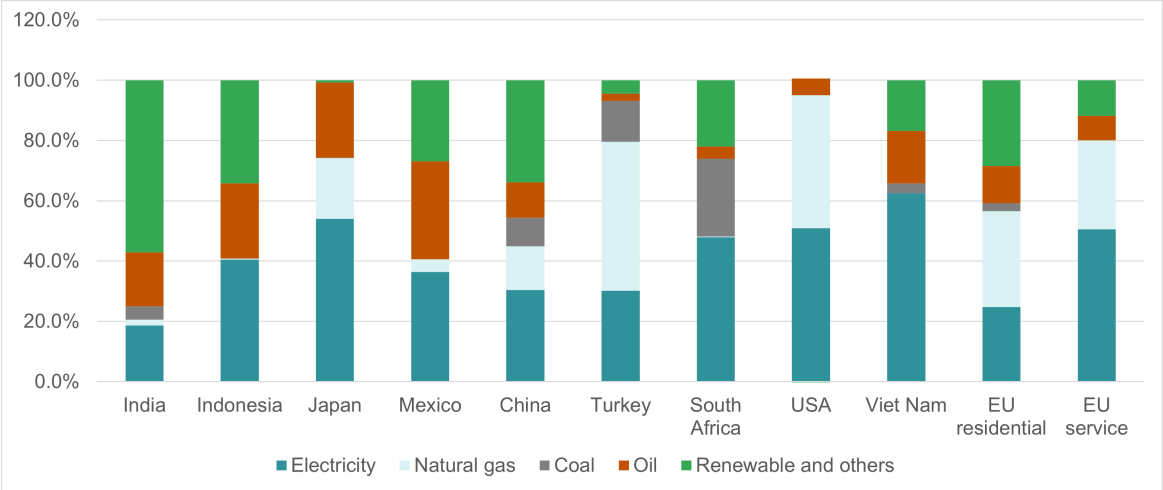

Figure 3 Fuel mix of the building sector (2020)

Source of data for all countries except the EU: Tables: Coal final consumption by sector; Electricity consumption by sector; Natural gas final consumption by sector; Oil products final consumption by sector; and Total final consumption (TFC) by sector on country pages of the IEA (IEA, 2023)

Data of EU household energy consumption: (Eurostat, 2022)

Data on the service sector in the EU is only available for 2019. (Odyssee-Mure, n.d.-b)

Between 2010 and 2020, the TFC by the building sector in China, India, Turkey and South Africa had increased, while it had decreased in the remaining countries. China has the most significant increase (34%), and Indonesia has the most significant decrease (32%). In both these countries, while the TFC of the services sector has increased, the substantial change in the TFC of the building sector is due to residential energy use. After peaking in 2005, Indonesia's residential energy consumption has been declining. This is partly due to the decline in traditional biomass use (International Energy Agency, 2022). China has been able to mitigate the growth of direct CO2 emissions by rapidly transforming the building sector. However, growth in building stock, floor area and population has led to an increase in TFC (International Energy Agency, 2021a).

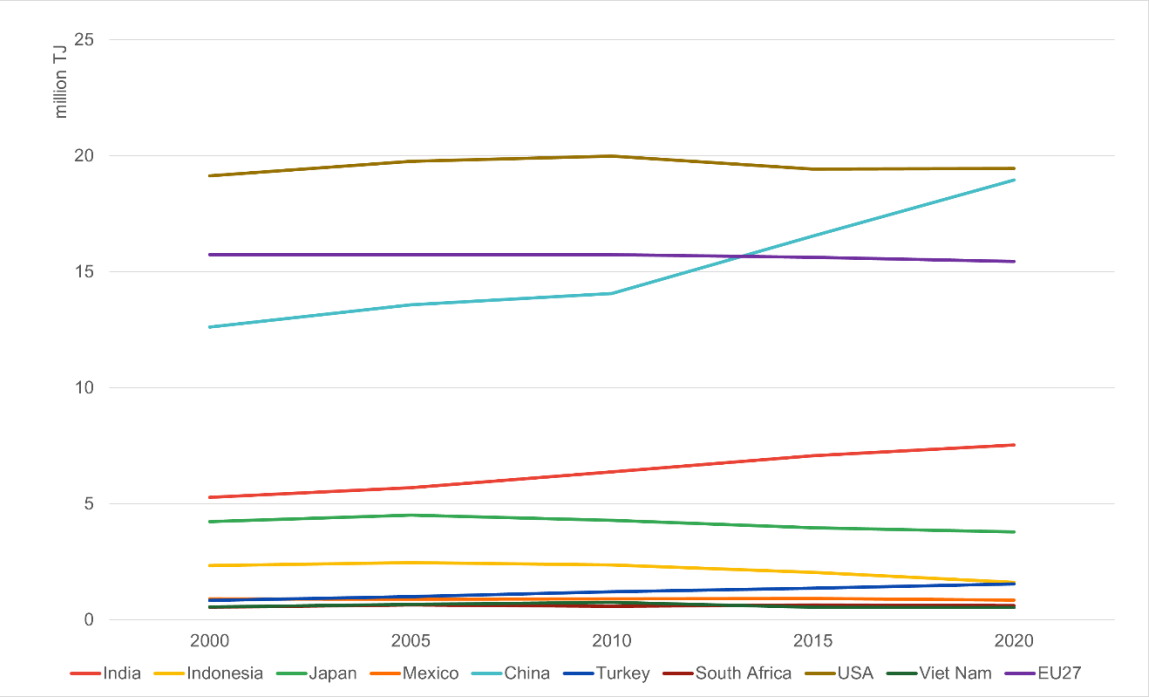

Figure 4 Change of total final energy consumption (2000-2020)

Source of data for all countries except the EU: Tables: Coal final consumption by sector; Electricity consumption by sector; Natural gas final consumption by sector; Oil products final consumption by sector; and Total final consumption (TFC) by sector on country pages of the IEA (IEA, 2023)

EU: *Source of data for the EU: Dataset from Eurostat: Final energy consumption by sector (Eurostat, 2023e)*

and Energy Consumption and Energy Efficiency trends in the EU, 2000-2020 (Tsemekidi et al., 2022)

The building sector has a significant share (i.e., above 40%) in the TFC in India and the EU. However, the share of CO2 emissions from buildings in India and the EU vary significantly at approximately 6% and 14%, respectively. This is due to the use of natural gas and electricity in the EU to meet its space heating and cooling needs and the high penetration of household appliances. In comparison, the use of air conditioners for space cooling and the share of appliances are low in India. However, they are increasing. For similar reasons, other countries with emerging economies and limited heating demand, such as Indonesia, Mexico, Vietnam and South Africa, have low CO2 emissions. CO2 emissions are high in Japan, Turkey, the US and the EU. These countries also have space heating needs and a relatively high share of natural gas in their fuel mix. Although there is a slight dip in the TFC in 2020 in some countries, e.g., Mexico, the general trend is upward in most countries, except Japan and the EU. This may attribute to population growth, rapid urbanisation, and an increase in appliance penetration. There is a clear downward trend in TFC in Japan and the EU, partly due to demographic decline and energy efficiency policies (in the EU).

6.2 USA

6.2.1 Major barriers and drivers to sectoral decarbonisation in USA

Structural

- Population growth and demand for housing and commercial space, as well as increased use of electronic devices, are drivers of energy demand and emissions in buildings (Leung, 2018; US Department of State and US Executive Office of the President, 2021).

Political

- There is no roadmap for overall building decarbonisation.
- While increased energy efficiency in buildings and the adoption of building codes are driving decarbonisation, Phasing out fossil fuel boilers and replacing them with electricity and technologies such as heat pumps remains a challenge (Leung, 2018; Reyna et al., 2021).
- A total of $20 billion is spent yearly on direct energy subsidies (Oil Change, 2017). Natural gas and crude oil receive 80% of the direct subsidies, while 20% is devoted to coal (ibid). In January 2021, President Biden made it clear that tackling subsidies for fossil fuels is a priority for his administration. However, there is still a need for legislative action (George & Elisha, 2021).

Politics

The interaction of federal, state, and local laws determines energy policy in the United States. Thus, policy implementation and stringency vary across different states. At the federal level, energy policy is set by the executive (Office of the President) and legislative (Senate and House of Representatives) branches of government and implemented by one of several departments, including the Department of Energy (DOE), the Department of Housing and Urban Development, and the Environmental Protection Agency.

Economic and Financial

The high upfront cost of energy efficiency and electrification and access to finance is considered one of the significant barriers to building decarbonisation, in particular, for overburdened and underserved communities (Kerry & Mccarthy, 2021; (US Department of State and US Executive Office of the President, 2021).

6.2.2 Policy instruments for decarbonising USA's building sector

Table 3 provides an overview of policy instruments in the USA for decarbonising its building sector.

Table 3 An overview of policy instruments for decarbonising USA's building sector

Policy instruments		Description
	Policy roadmaps for building decarbonisation	No national-wide building decarbonisation roadmap

Governance & planning instruments	(including cooling/heating decarbonisation)	
	Pricing mechanisms	The use of energy from all sources, such as fossil fuels, biofuels and renewables, is not subject to any taxes (e.g., excise duties) in the residential and commercial sectors. In addition, energy sources used to generate electricity and final electricity consumption are not subject to taxation (OECD, 2020). 12 states have introduced carbon pricing policies. Two main types of pricing are generally used: a carbon tax and a cap-and-trade system(Hibbard et al. 2018) There are also initiatives at the city level. For example, Boulder, Colorado, introduced a tax on electricity use in 2006 as part of its Climate Action Plan (CAP) to reduce the city's greenhouse gas emissions by 80 percent below 2005 levels by 2025. The CAP tax provided $1.8 million in funding for the community's climate work, including investments in direct cash transfers to homeowners to fund energy efficiency upgrades, local solar energy projects, regulations and building codes (City of Boulder, 2022).
	Energy Efficiency Obligations	Energy efficiency resource standards (EERS) is a long-term binding energy savings target for utilities or third-party program administrators, adopted by 27 states over the past 20 years. Traditionally, EERS policies were designed to encourage savings for specific energy resources, including electricity and natural gas. Many states have revised their EERS policies to go beyond energy efficiency due to the increased focus on emissions reductions, least-cost resource planning, equity, and the value energy efficiency can provide to the grid. They have taken three main approaches: adopting resource-specific targets, fuel-neutral targets, and multiple-goal approaches that may combine the two approaches above (Gold et al., 2019).
	Energy Efficiency Funds	The Inflation Reduction Act (IRA) 2022, along with the 2021 Infrastructure Investment and Jobs Act (IIJA), allocate more than $25 billion for programs and tax incentives to improve the energy efficiency and reduce GHG emissions from existing homes (ACEEE, 2023).
	Removing subsidies for fossil fuel	Since 2016, the USA, a part of G7, committed to phase out “inefficient” fossil fuel subsidies by 2025. In January 2021, President Biden made it clear that tackling subsidies for fossil fuels is a priority for his administration. However, there is still a need for legislative action (George & Elisha, 2021).
	Presence of a dedicated political body	The US Department of Energy (DOE) is responsible for energy conservation, energy research, energy generation, and the nation’s nuclear programs.
Regulatory instruments	Building energy code	The DOE works closely with two popular energy codes, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1 (for all buildings except low rise-residential buildings) /90.2 (for low-rise residential buildings) and the International Energy Conservation Code (for commercial buildings) and International Residential Code (IECC and IRC, developed by the International Codes Council). (Office of the Energy Efficiency & Renewable Energy, n.d.-c). Although building energy codes are not mandatory at the national level, several states are developing their codes based on either Standard 90.1 or IECCC. Some states use much older versions of the codes, and some states have not adopted building

		energy codes (Office of the Energy Efficiency & Renewable Energy, n.d.-c). Both codes have also become increasingly more stringent in the last decades. The 2021 IECC includes Zero Codes for residential and commercial buildings (based on the Architecture 2030 ZERO Code) as appendices (ICC, 2020). Some states and municipalities have also adopted zero-energy building codes and initiatives. California, for example, aims to achieve zero-energy homes and commercial buildings by 2020 and 2030 respectively (Perry, 2018). The state continues to improve the efficiency of the code in consultation with utilities, homeowners and architects. Similarly, the state of Oregon has zero-energy programmes benefiting from incremental increases in code stringency. Most local governments have building departments that require builders to obtain permits before they can start construction. After the plans are approved, field inspections (by third parties) occur at multiple intervals during construction for verification. The DOE Building Energy Codes Program (BECP) provides resources and tools to assist states in evaluating compliance (Office of the Energy Efficiency & Renewable Energy, 2016). The U.S. Energy Administration (EIA) collects detailed end-use energy consumption data in residential and commercial buildings for selected years (EIA, n.d.).
	Phasing out fossil fuel boilers	No national-wide plan exists for phasing out fossil fuel boilers. A few US states made legislations allowing local governments to implement gas bans and electrification codes in new buildings (Christopher, n.d.). Several cities (e.g., Berkeley, San Francisco, Seattle, Denver and New Jersey) have banned natural gas for space heating in new buildings or mandated that new buildings to be fully electrified (Pierson, 2022).
	Product-specific minimum energy performance standards (MEPS)	MEPS in appliances is regulated by the Appliance and Equipment Standards Program and implemented by the Building Technologies Office (BTO). This includes residential space cooling and heating products such as central air conditioners and heat pumps, dehumidifiers, district heating equipment, stoves, portable and room air conditioners; and commercial space cooling and heating equipment such as packaged boilers and unitary air conditioners (USDOE, n.d.-a, n.d.-i). Number of appliances with MEPS:42, Key appliance groups:4 (Subramanian, Bastian, Hoffmeister, et al., 2022)
Economic instruments	Financial incentives or Energy Saving Auction	The federal government and most states have incentive programmes such as capital funding and grants, preferential and revolving loans, tax credits, subsidised energy audits and specific programmes for residential and commercial buildings (ACEEE, 2022; de la Rue du Can et al., 2021). Tax: Through the Federal Homebuilder Tax Credit Program, new homes are eligible for a $2,500 tax credit if they meet the requirements of the ENERGY STAR program. Similarly, manufactured homes are eligible for a $2,500 tax credit if they meet ENERGY STAR requirements (Energy Star, n.d.). 25C Energy Efficient Home Improvement Credit: A long-standing federal tax credit for home energy improvements such as insulation, windows, heat pumps, and furnaces. The credit is now increased to 30% of the cost.

		179D Energy Efficient Commercial Building Deduction: A long-standing federal tax provision. IRA provides tax deductions of $0.50–5.00 per square foot of floor area to owners of commercial buildings and mid-rise and high-rise multifamily buildings (new and energy retrofits) (ACEEE, 2023). Loan: Energy Efficiency and Climate Resilience in Affordable Housing Program: This is a new $1 billion grant and loan program for affordable apartments to improve energy and water efficiency, air quality and sustainability, and climate resilience, including solar power, energy storage, and building electrification. The target group is the multifamily building owners assisted by the Department of Housing and Urban Development (HUD) (ACEEE, 2023) . Subsidies: LIHEAP is a federally funded program aimed at assisting low-income households who pay a high portion of their income to meet their energy needs, including, e.g., one-time financial assistance for utility bills and free energy efficiency upgrades to low-income households (California Department of Community Services & Development, n.d.) High-Efficiency Electric Home Rebate Program: This $4.5 billion DOE program provides rebates to low- and moderate-income households to install heat pumps and other efficient electric equipment, insulation and air sealing and upgrading electric service and wires (California Department of Community Services & Development, n.d.). Energy saving auction: Utilities have energy saving auction programs in their portfolio to meet their EERS, e.g. such as the Brooklyn Queens Demand Management Program (BQDM) or the PJM Base Residual Auction (BRA)(Anatolitis & Schlomann, 2022).
Promoting business models and financing	Policies promoting energy services-ESCOs	In the US, the guaranteed savings model of ESCOs is widely used. US ESCOs have existed for over four decades, with annual industry growth of 3.4% between 2014 and 2018 and revenues of approximately $6 billion in 2018 (Stuart et al., 2021). Most US states have a long history of regulating, administering or overseeing ESCO programmes and contracts, with rare exceptions such as Iowa (ACEEE, 2020). The National Association of Energy Service Companies (NAESCO), a leading advocacy and accreditation organisation for energy service companies, offers accreditation for energy service providers, energy service companies and energy efficiency contractors (NAESCO, n.d.) As part of the Federal Energy Management Program (FEMP), the DOE publishes the DOE Qualified List of Energy Service Companies (USDOE, n.d.-c). The Office of Energy Efficiency and Renewable Energy's State and Local Solution Centre provides model Energy Savings Performance Contract (ESPC) project documents as resources for developing or updating procurement and contracting documents for ESPC projects and programmes (USDOE, n.d.-g). Ratepayer-funded energy efficiency programmes under the EERS appear to be an essential source of project funding (Stuart et al., 2021).

		Energy-as-a-Service (ESA) and Managed Energy Services Agreements (MESA) are available in the market for both residential and commercial customers (Better Buildings Initiative, n.d.).
	Policy promoting One-Stop-Shops	The Better Buildings Initiative and its sub-programmes develop and promote replicable market solutions, energy efficiency alliances and solutions to decarbonise the building stock (Better Buildings, n.d.-b). The Los Angeles Better Buildings Challenge (LABBC) is expanding its city-sponsored building retrofit programmes to increase multi-million/dollar investments in municipal, affordable housing, and commercial buildings, to increase investments to $25 million in partnership with the Better Buildings Challenge (US DOE, n.d.-b). The programme and its platform connect building owners with technical advisors, technology providers, and financing solutions to accelerate energy efficiency retrofit toward net zero carbon by 2050 (LA-BBC, 2020).
Information instruments	Building rating and disclosure policies	The Home Energy Score, developed by the DOE, is designed to help assess the energy efficiency of homes. The certificate shows the home's energy score, compares it to the average home score, and gives a score with improvements. That is if energy efficiency improvements are made (Better Buildings, n.d.-a). Similarly, there is ENERGY STAR certification for commercial buildings (USDOE, n.d.-e). The Energy Star label is a comparative label that certifies a building on a scale of 1-100, with a score of 75 or higher indicating that the building performs better than 75% of similar buildings in the country. Its main strength is that it is based on measured energy consumption, verified by a third party and renewed annually. However, it is a voluntary scheme, and, unlike an EPC scheme, it is difficult to identify areas where building performance can be improved, for example, through detailed renovation recommendations. Furthermore, several green building rating and certification systems are popular in the US, including the National Association of Home Builders' ICC 700 National Green Building Standard (NGBS), the Green Building Initiative's Green Building Assessment Protocol for Commercial Buildings (Green Globes), the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED), and the International Living Future Institute's Living Building Challenge (EPA, 2014).
	Energy labelling schemes of products	The EnergyGuide label for appliances requires certain appliances to display a label showing their energy costs compared to the cost range of similar products. Some labels include estimated annual energy/electricity consumption (FTC, 2013). Appliance group:16; Mandatory, Continuous (Subramanian, Bastian, Hoffmeister, et al., 2022)
	Provision of information	At the national level, web-based and desktop tools are available to check the compliance of commercial and residential buildings with the energy code (Office of the Energy Efficiency & Renewable Energy, n.d.-b). At the state level, the Database of State Incentives for Renewables & Efficiency (DSIRE) provides information on the various incentives offered by different states for renewable energy and energy efficiency (DSIRE, n.d.).
	Policies supporting targeted energy advice	Home Energy Performance-Based Whole-House (HOMES) Rebates: IRA provides two approaches under this program: Modeled and measured. For modelled savings, a contractor will do an energy assessment of the home, design a retrofit package, and model the savings.
R&D policies	R&D policies foster innovations	The Building Technologies Office works with DOE-funded national laboratories to develop and demonstrate energy-efficient technologies, including advances in heating, ventilation and air

		conditioning (HVAC), building envelope, windows, building energy modelling, and sensors and controls (USDOE, n.d.-h). The DOE Office of Building Technologies leads the Advanced Building Construction (ABC) Collaborative initiative to achieve a carbon-neutral building stock by 2050 (Office of the Energy Efficiency & Renewable Energy, n.d.-a). The ABC initiative takes a multi-pronged approach to provide scalable solutions for affordable, high-performance, low-carbon new buildings and retrofits. This includes investment in technology R&D to develop off-site and modular construction technologies using mechanical systems, robotics and 3D printing with low-carbon, high-efficiency systems. Collaborators and support will include technology companies, product manufacturers, research institutes, cities, developers, and construction companies. To phase out fossil fuel technologies for space heating and water cooling, the DOE is working with stakeholders through its Energy, Emissions and Equity (E3) initiative to develop solutions to increase access to low-carbon technologies (US DOE, n.d.). Notable E3 initiatives include the Residential Cold Climate Heat Pump Challenge and the Advanced Water Heating Initiative to advance heat pump technologies for space heating and water heating. IIJA provided $500 million of competitive grants for energy efficiency, renewable energy, and alternative fuel vehicle improvements to public schools. IIJA also offered $50 million for an Energy Efficiency Materials Pilot Program to provide competitive grants to improve the efficiency of buildings owned by non/profit organisations (ACEEE, 2023).
Policies supporting capacity building	Training and education: Certification of qualified actors	The DOE and Better Buildings Affiliates offer training and education opportunities in various building efficiency programmes (Better Buildings, n.d.-c). DOE grants states to train individuals to conduct energy audits or surveys of commercial and residential buildings through the Energy Auditor Training Grant Program (USDOE, n.d.-d). To facilitate and simplify the process of standard retrofit measures, NREL has developed specifications that define standard procedures and minimum acceptable results for specific measures such as improving air sealing, insulation, heating, cooling and ventilation systems (NREL, n.d.). Furthermore, NREL provides 'Guidelines for Accredited Training for Home Energy Professionals', which includes a job task analysis to help energy professionals perform audits in single and multi-family homes (USDOE, n.d.-f).
Lead by example	Lead by example	The “Federal Sustainability Plan” (Executive Order 14057) aims to achieve net-zero emission buildings by 2045 (Office of the Federal Chief Sustainability Officer - Council on Environmental Quality, n.d.). All new buildings and major renovations with a gross floor area of more than 2,500 m2 will be designed, built and operated to achieve net zero emissions by 2030. In December 2022, the Biden-Harris Administration announced the first-ever energy and climate performance standard (Federal Building Performance Standard (BPS)) for the country's 300,000 Federal buildings (Office of Federal Chief Sustainability Officer, n.d.).

6.3 EU

6.3.1 Major barriers and drivers to sectoral decarbonisation in EU

Structural

GHG emissions in the EU have been decreasing since 2005. However, decarbonisation efforts were partly offset by the floor areas per capita. The average floor area per capita increased by 15% between 2010 and 2022 (Bartek-Lesi et al., 2022). It results from the increasing size of dwellings and households (Eurostat, 2022; OPENEXP & EEB, 2021). Thus, sufficiency in floor areas becomes a key factor for decarbonising the EU building sector.

Political

In 2020, fossil-fuel subsidies in the EU reached EUR 50 billion. Between 2015 and 2020, while fossil-fuel subsidies had increased in a few MSs, they had decreased in most Member State (MSs). At the EU level, the share of fossil-fuel subsidies within the GDP had remained un-changed (European Commission, 2022). A driver for decarbonisation is the understanding that it means a modernisation pro-gramme for the EU's industries, as documented e.g. by the Green New Deal initiative and its corresponding legislation processes.

Politics

According to the EU subsidiarity principle and considering the local peculiarities and climatic differences, MSs must transpose most EU Directives into national law, e.g., within three years. the Energy Performance of Buildings Directive (EPBD, 2002/91/EC) introduced in 2002 was the first cohesive EU legal act on building energy policy and was amended in 2010, 2018, and 2023. The progress of the EPBD transposition varies and is relatively slow in several MSs (Zangheri et al., 2021).

Economic and Financial

According to the European Commission's impact assessment (IA) for the recast of the EPBD (European Commission, 2021), major barriers to building decarbonisation include:

- High upfront costs and affordability of energy renovations for deep renovation;
- Split incentive is a common barrier across many EU countries: 16 MSs underline the issue of split incentives as one of the most relevant barriers to energy renovations
- Lack of access to financing for affordable renovations was identified as another key barrier. Private financing products for energy renovations are not sufficiently developed across MSs,
- Limited public funds, public financial support not sufficiently targeted towards deep renovation

- There is generally a lack of information on available funding opportunities and the potentially lower credit risks of energy efficiency investments.

Capacity

- Local administration lacks technical expertise and capacities for energy efficiency renovation programmes.
- There is a lack of skilled workforce in the construction sector across its value chain.

(European Commission, 2022).

Information

According to the IA, there is a significant lack of information and awareness from private, public, and professional owners or tenants of buildings on the overall energy performance of their buildings, potential energy efficiency improvements, costs and benefits, and carbon performance. Although energy performance certificates (EPCs) have long been implemented and can inform stakeholders about energy-related information, the EPC schemes are criticised to be insufficient.

6.3.2 Policy instruments for decarbonising EU's building sector

Table 4 presents an overview of policy instruments in the EU for decarbonising its building sector.

Table 4 An overview of policy instruments for decarbonising EU's building sector

Policy instruments		Description
Governance & planning instruments	Policy roadmaps for building decarbonisation	The EU aims to transform its building stock into zero-emission by 2050 with its revised Energy Performance of Buildings Directive (EPBD) as a part of Fit for 55 (European Commission, 2021b; European Parliament, 2023b)' It sets targets for all building types. MSs shall develop long-term renovation strategies, and after the current recast, national building renovation plans to achieve a highly energy efficient and decarbonized building stock by 2050 MSs shall ensure that from the following dates, new buildings are zero-emission buildings: (a) from 1 January 2026, new buildings occupied, operated or owned by public authorities; and (b) from 1 January 2028, all new buildings.[2] For existing buildings: MEPs will mainly target the 15% worst-performing buildings in the country, i.e.,

[2] *This is the proposal of European Parliament in 2023, which is in trialogue negotiations. The proposal is more ambitious than the first proposal by the European Council in 2021, i.e., for new public buildings by 2027 and for all new buildings 2030; the worst-performing buildings only needs to improve to class F; the renovation rate to at least doubled by 2030.*

		class G of Energy Performance Certificate (EPC).[3] Residential buildings would have to achieve at least energy performance class E by 2030 and D by 2033. Non-residential and public buildings must achieve the same classes by 2027 and 2030, respectively. A key goal of the Directive is "triggering and supporting building renovation to at least triple the current renovation rate by 2030." (European Parliament, 2023b).
	Pricing mechanisms	At the EU level, the Emission Trading Scheme (ETS) has been established since 2005, representing approximately 40% of total GHG emissions (Thomas, Sunderland, et al., 2021). The EU ETS currently covers 30% of total building emissions, including emissions from fossil fuel district heating (>20MW) and indirect emissions from electricity use (European Commission, 2020). The limited coverage would be addressed through the EC's proposal of extending ETS to fossil fuel use in buildings by 2027 (European Parliament, 2022).
	Energy Efficiency Obligations	Article 7 of the current Energy efficiency directive (EED) requires all MSs to establish either EEOs or alternative policy measures, to achieve obligated annual savings of final energy consumptions.
	Energy efficiency funds	Energy efficiency funds have started in the EU since the 1990s and have been implemented in 11 MSs and Norway. At the EU level, the European Structural and Investment Funds (ESIF) are the essential funding scheme for building energy renovations (European Commission, n.d.-a). The Social Climate Fund (SCF) is the first EU Fund dedicated to providing financial support to vulnerable households, financing structural investments, and providing temporary direct income support to these households. The funding source is the new carbon price introduced in 2027 by the new ETS for road transport and buildings (ETS2). Among others, the investments will enable vulnerable citizens to renovate their homes, to adopt energy efficient technologies, and to access renewable energy (CAN Europe, 2023).
	Removing subsidies for fossil fuel	To achieve its Paris Agreement goal, the EU has committed to phasing out all fossil fuel subsidies by 2025 (Coolproduct, 2020).
	Presence of a dedicated political body	Directorate-General Energy; government departments of the 27 Member States
Regulatory instruments	Building energy code	Ever since the first version of the EPBD in 2002, Member States had to implement building energy codes with energy performance requirements for new buildings and for existing buildings undergoing major renovation for whatever reason. Many Member States had building energy codes before

[3] *The worst performing buildings targeted are buildings with the lowest energy performance class (class G), which are the worst-performing 15% of the national building stock in each MS.*

		the EPBD, some dating back to the 1970s, and Sweden even earlier. The EPBD was amended in 2010, 2018, and 2023. The newest EPBD introduces EU-wide mandatory minimum energy performance standards (MEPS) for all types of existing buildings (European Parliament, 2023a)
	Product-specific minimum energy performance standards (MEPS)	These exist for 42 types of products (Subramanian et al., 2022); mandatory; cover all following end uses: Space heating, Air-conditioning, Water heating, Refrigeration, and Lighting (European Commission, n.d.-b)
	Phasing out fossil fuel boilers	The EC has called for phasing out fossil fuel heating appliances: REPowerEU: The EC suggests banning the retail of new fossil fuel boilers by 2029 (Dao, 2022). Revised EPBD: 2035 is the deadline suggested by the European Parliament for total phasing out fossil fuel boilers (European Parliament, 2023b).
Economic instruments	Financial incentives	Economidou et al. (2019) identified 129 instruments supporting building energy renovations in the EU . Grants (61%) have been implemented in all MSs. Soft loans and other loan programs (19%) are available in over half of the EU countries. Loans and soft loans are available for all building types (new, existing, residential, and non-residential) in more than half of the EU countries, some supported by state guarantees and others designed as revolving funds. Zero-interest rate loans are available in, e.g., Belgium, Croatia, and France. These are typically directed towards the most socially vulnerable groups. As of 2019, tax incentives (10%) had been used in eight MSs, commonly in income tax deductions or credits or, less commonly, VAT reduction, such as in Belgium, France and the Netherlands. (Economidou et al., 2019). All energy efficiency measures are eligible, ranging from building envelope improvements, building technical systems, connection to district heating, and renewable heat, to renewable electricity generation systems (Bertoldi, Economidou, et al., 2021; European Commission, 2022). The soft loan programs offer zero interest rates and target low-income households in some countries, e.g., Belgium, Croatia and France. The loan program can also be combined with grants. For low-income households, different countries have implemented grants (e.g., France, Czech, Ireland), zero-interest loans (Belgium, Croatia and France), and tax credits (e.g. France) (Economidou et al., 2019). Only four EU countries have EE auctions experience (Anatolitis & Schlomann, 2022).
Promoting business models& financing	Policies promoting energy services- ESCOs	Article 27 of EED requires MSs to consider a policy package for promoting energy services, ranging from regulatory, information, to facilitation mechanisms:

		Ensuring access to information on available energy services and financial instruments to support energy efficiency service projects; Encouraging the development of quality labels for ESCOs or their services; Providing model contracts for Energy Performance Contract; Providing information on best practices in energy performance contracting; Providing information about the current and future development of the energy services market; Remove the regulatory and non-regulatory barriers that impede the uptake of ESCO services; Enabling independent market intermediaries to play a role in stimulating market development (Fuglsang, n.d.) Remove the regulatory and non-regulatory barriers that impede the uptake of ESCO services;
	Policy promoting One-Stop-Shop	EED emphasises the role of one-stop shops: "It is necessary to increase the role of independent market intermediaries including one-stop shops or similar support mechanisms (Fuglsang, n.d.) EPBD recast: Article 15a suggested by the European Parliament would be dedicated to "One-stop-shops for energy efficiency in buildings" • It defines various roles of OSS to support locally developed projects by providing technical, administrative and financial advice and assistance; • The Commission shall cooperate with the European Investment Bank, MSs, and regions to facilitate the functioning and continuity of funding of OSS for energy efficiency in buildings until at least 31 December 2029; • The Commission shall provide guidelines to MSs to develop those OSSs; • A harmonised approach throughout the Union should be created.
Information Instruments	Building rating and disclosure policies	Energy performance certificates (EPC) are required for all residential and non-residential buildings, new and existing. According to EPBD , including in its ongoing recast (European Parliament, 2023a), buildings or building units which are offered for sale or rent must have an EPC. MSs shall establish independent control systems for energy performance certificates and carry out sample checks or other controls to ensure compliance with these requirements. However, the authority for monitoring and the sample size significantly varies between various member states and also between regions in a country. On-site inspection for EPC assessment is mandatory for all buildings or for some categories of buildings (e.g., existing/residential/non-residential/public).

		Most countries have mandatory official or certified private software for compliance checking. (Gokarakonda et al., 2020).
	Energy labelling schemes of products	This exists for 25 product groups; Categorical (Subramanian et al., 2022);
	Policies supporting targeted energy advice	Article 26 of EPBD (recast) (Article 20 of current EPBD) (European Parliament, 2023a)requires that MSs take necessary measures to inform the owners or tenants of buildings and building units of different methods and practices that lead to enhanced building energy performance. As of 2019, 18 MSs reported having targeted energy advisory services for energy renovation (Šijanec Zavr & Building and Civil Engineering Institute ZMRK, n.d.).
RD&D policies	RD&D policies foster innovations	Horizon 2020 Energy Efficiency supports innovation through research and demonstration of more energy-efficient technologies and solutions and market uptake measures to remove market and governance barriers by addressing financing and regulations and improving skills and knowledge. The programme supports the research, demonstration, and market uptake of energy-efficient technologies. Funds are available to support energy-efficient buildings, industry, heating and cooling, SMEs and energy-related products and services, as well as for improving the attractiveness of energy-efficiency investments (European Commission, n.d.-c).
Policies supporting capacity building	Training and education: Training programs for local governments on requirements and compliance Training and certificate programs for building inspectors Sponsored university degree programs on building energy efficiency	EPBD (recast) (European Parliament, 2023a) Article 3: Building renovation plans of MSs "should provide for sufficient skilled workers and effective skilling and training initiatives" Article 15: MS shall monitor the availability of skills and skilled professionals and develop measures and financing to promote education and training programmes Article 22: Independent experts who carry out EPC assessment, renovation passports establishment, the smart readiness assessment, and the inspection of heating systems and air-conditioning systems are certified Article 23: Where appropriate and feasible, MSs "shall ensure that certification or equivalent qualification schemes are available for providers of integrated renovation works"
	Certification of qualified actors *Policy-makers should lay down which certification is necessary for which services (e.g. special certification for issuing an Energy Performance Certificate or calculating the energy performance vs the requirements of MEPS or energy efficiency building codes).*	
Lead by example		EPBD (recast) (European Parliament, 2023a)

		MSs shall ensure that, from 1 January 2026, new buildings occupied, operated or owned by public authorities are zero-emission buildings. Article 6 of EED (Exemplary role of public bodies' buildings) requires MSs to ensure that at least 3 % of the total floor area of heated and/or cooled buildings owned by public bodies of the following categories and of buildings for social purposes is renovated each year to at least be transformed into nearly zero-energy buildings or zero-emission buildings where technically feasible and cost-effective: • Buildings owned by public bodies; • Buildings newly occupied by public bodies; • Buildings occupied by public bodies when reaching a trigger point (renewal of rental, sale, change of use, significant repair, or maintenance work).

6.4 China

6.4.1 Major barriers and drivers to sectoral decarbonisation in China

Structural

China has experienced rapid urbanisation in the last decades, which rises from 36% in 2000 to over 65% in 2022 (Statista, 2023). Together with the increasing living standards, urbanisation has driven and will continue to drive the growth of dwelling numbers and floor area per capita (IEA, 2021a).

Space heating and cooling have the highest share in building energy consumption and are highly dependent on floor area. Higher income and living standards will drive demand for heating and cooling to deliver thermal comfort (IEA & Tsinghua University, 2015). The ownership of air conditioners has more than doubled in the last two decades in China (IEA, 2019, cited in IEA, 2021).

Political

- In northern China, where district heating is provided, the heating price is still relatively low, leading to few energy-saving incentives. In many areas, heating is still paid based on floor areas.
- Natural gas is regarded as clean heating. Thus, replacing coal with natural gas is subsidised.

Politics

The governance of building energy efficiency in China is top-down in nature, where policies are designed by the national government and implemented by each level of local government.

Successful implementation is determined by the willingness of local governments. The central government introduced the target responsibility system (TRS) to incentivise local governments. It contains specific and measurable targets to be achieved under the responsibility of local leaders. Failure to achieve the key targets will result in the penalisation of local leaders. Energy conservation TRS (ECTRS) was introduced in 2006, in which energy intensity is a major indicator. The ECTRS was reformed in 2016 to additionally include energy consumption caps (Lo, 2020). However, there is no specific ECTRS for the building sector.

Economic and Financial

- The upfront costs for energy retrofit and clean heating are high. Local governments also do not have sufficient financial resources to subsidise energy renovation (Ding & Liu, 2022).
- There is a lack of access to financing by individual households to cover the upfront costs.
- China has the world's largest and fastest-growing ESCO market. However, small- and medium-scale ESCOs, who cover the upfront costs of energy retrofits and share the energy-saving benefits with users, also lack access to financing (Suerkemper et al., n.d.; Zhu, 2021) due to their limited assets and weak balance sheets, financial track record, and low awareness and knowledge of funding opportunities.
- The operational cost of heat pumps varies across provinces. It is very high in some provinces due to the high electricity price.

Capacity

The lack of capacities of building professionals, e.g., designers and construction workers, leads to low-quality energy renovation, e.g., building insulation falls short after renovation (Ding & Liu, 2022).

Information and awareness

For commercial buildings, owners, investors, and relevant service providers focus instead on building core functions (e.g., providing space) and creating economic value. They lack a systematic understanding of the benefits of energy efficiency measures (Wang, 2020).

6.4.2 Policy instruments for decarbonising China's building sector

Table 5 presents an overview of policy instruments in the China for decarbonising its building sector.

Table 5 An overview of policy instruments for decarbonising China's building sector

Policy instruments		Description
Governance & planning instruments	Policy roadmaps for building decarbonisation	The Chinese government aims to peak CO_2 emissions from its building sector by 2025. The Plan specifies the targets of building energy performance (new and

		existing), electrification, and renewable generation and use in residential, commercial, and public buildings (The Government of China, 2022).
	Pricing mechanisms	China launched its first national ETS in 2021 (OECD, n.d.-b). The building sector is not expected to be a part of the national ETS before 2025 (Xiliang et al., 2021).[4] In China, only diesel and oil are directly taxed in the residential and commercial sectors (OECD, n.d.-b).
	Energy Efficiency Obligations (EEO)	EEO was introduced in 2011, which requires the two grid companies (State Grid and Southern Grid) to achieve a minimum of 0.3% annual energy savings in sales volumes and demand. The grid companies can achieve the target by establishing energy service companies to implement energy efficiency projects (National Energy Administration, 2011).
	Energy efficiency funds	The national government has established dedicated national funds for energy retrofitting and clean heating in northern China. The national pilot program was launched in 2017. In 2017-2021, the national government supported more than 60 pilot cities with around RMB 62 billion in total (9176 million USD 2017) (The Government of China, 2017)
	Energy and urban planning	China has the largest district heating network in the world. In the urban areas of northern China, all buildings are connected to district heating.
	Removing subsidies for fossil fuel	China spent USD 22 billion on oil subsidies in 2021, making it the second largest provider of fossil fuel subsidy payments globally (IEA, n.d.).
	Presence of a dedicated political body	The MOHURD is responsible for urban-rural development, including building decarbonisation.
Regulatory instruments	Building energy code	The Chinese government introduced the building energy code in the 1980s and has amended the code several times to achieve a higher energy performance since then: energy saving of 30% (1986),50% (2001), 65% (2010), and 75% (in the extremely cold and cold regions, 2018), compared to the reference building of the 1980s (NDRC, 2020). The building energy code is mandatory for all new

		residential, commercial, and public buildings only in the urban area.
	Product-specific minimum energy performance standards (MEPS)	Number of appliance types with MEPs:40, groups: 4 (Subramanian, Bastian, Jennings, et al., 2022)
	Phasing out fossil fuel boilers	Since 2017, the Chinese government has launched a clean heat program to prohibit coal boilers and to replace coal with clean fuels for residential heating in northern China (The Government of China, 2017). On the other hand, since natural gas is recognised as a clean fuel, the local governments have provided subsidies for purchasing natural gas boilers and consuming natural gas during the operation (Beijing Sustainable Development Association, 2022).
Economic instruments	Financial incentives or Energy Saving Auction	Subsidies: From 2017 to 2021, the central government invested RMB 62.08 billion to support energy retrofit and clean heating for residential buildings in 63 pilot cities (Environmental Planning Institute & Ministry of Ecology and Environment, 2022). Since 2011, the national government has launched and implemented pilot projects in major cities for energy renovation of public buildings. In total, there are three batches. The first two batches of pilots(2011-2016) received subsidies from national and local governments. The national government issued the Green Building Action Plan in 2013, requiring local governments to provide financial incentives for advanced green buildings (Government of PR China, 2013). Since 2012, national and local governments have started implementing subsidies for energy-efficient appliances. In 2019, the national government issued the Implementation Plan for Further Optimizing Supply, Promoting Steady Growth of Consumption, and Facilitating the Formation of a Strong Domestic Market, which requires local government to financially support the purchase of green smart appliances (Nie et al., 2021). Soft loans: The national government has issued several policies to promote green financing(People's Bank, 2021). However, green financing for buildings has been limited.
Promoting business	Policies promoting energy services- ESCOs	Supportive policies for the ESCO market among public institutions •

models& financing		Business model selection: Public institutions should prioritise Energy Performance Contracts during their energy efficiency retrofitting; the government actively supports public procurement of EPC services and explore the business model of energy use and cost custody. • Payments to EPCs treated as energy expenses in public spending: When government agencies provide EPC services for energy retrofitting, the payments to ESCOs under EPCs should be treated and reported as energy expenses in accounting • Public institutions may seek EPCs in energy conservation: Public Institutions may adopt EPC and commission ESCOs to conduct energy conservation diagnosis, designing, financing, retrofitting, and operation management. During their EE retrofitting, public institutions should conduct an energy audit and cost-benefit analysis, specify the energy-saving targets, and check and assess whether the energy savings targets are achieved through measurement and data collection. • Public institutions can preserve part of their energy cost-saving and other incentives: Improve the subsidy policies for EPCs by public institutions and the partial preservation of energy cost-saving, stimulate social investment in energy conservation projects in public institutions, and facilitate the development of the ESCO sector (Zhu, 2021)
	Policy promoting One-Stop-Shops	No. Only pilot.
Information Instruments	Building rating and disclosure policies	Mandatory for public buildings and large-scale commercial buildings in several provinces and cities. Voluntary for residential buildings and small-scale commercial buildings; At the local level, especially in the middle and western regions of China, there is a lack of certified rating institutions and practitioners to implement energy efficiency policies, projects and standards (Yu et al., 2019).
	Energy labelling schemes of products	Mandatory Categorical, number of appliance groups covered is 34 (Subramanian, Bastian, Hoffmeister, et al., 2022)
	Policies supporting targeted energy advice	No

RD&D policies	RD&D policies foster innovations	Various RD&D programs are supporting building decarbonisation. For example, the National Key Research and Development Programme and the International Cooperation Program of the Ministry of Science and Technology supported the establishment of the overall framework of net-zero energy buildings in China, including R&D of technology and key products, demonstration in different climate zones and with different building types, development of various standards (Xu & Zhang, n.d.).
Policies supporting capacity building	Training and education: Certification of qualified actors	According to *Regulations on the Management of Energy Efficiency in Civil Buildings* (Ministry of Construction, 2005): Organisations engaged in building energy efficiency and related activities should train their practitioners. Building energy efficiency standards and technologies should be made compulsory as a part of the continuing education of registered urban planners, registered architects, registered survey and design engineers, registered supervision engineers, etc. Various associations affiliated with the MoHURD also provide training to professionals required in the law. Furthermore, the MoHURD also sets up an online training management information system for urban and rural construction industry employees, including, e.g., the info on certification issuing organisations and qualification verification.
Lead by example		The 14th Five-Year Plan for Energy Conservation in Public Institutions includes energy consumption per unit of floor space, total energy consumption per capita and carbon emissions per unit of floor space as binding indicators, requiring the three indicators to decrease by 5%, 6% and 7% respectively by 2025 compared to 2020 (Government of China, 2021).

6.5 India

6.5.1 Major barriers and drivers to sectoral decarbonisation in India

Structural

The growth in built-up areas and buildings is due to rapid urbanisation, population growth and income effects. Urbanisation has increased from 26% in 1990 to 34% in 2019, and many cities are experiencing rapid growth (International Energy Agency, 2021b).

Political

There is no roadmap for achieving net zero buildings.

Politics

The Ministry of Environment, Forests and Climate Change (MOEFCC) oversees key functions related to carbon mitigation and climate change. The promotion of energy efficiency in general and buildings in particular falls under the Ministry of Power (MOP) and its statutory body, the Bureau of Energy Efficiency (BEE) and the State Designated Agencies (SDAs). The BEE has been responsible for developing building energy codes and MEPS for appliances. The Ministry of New and Renewable Energy (MNRE) promotes renewable energy technologies, including rooftop solar.

Lack of inter-ministerial coordination and capacity building among government agencies at the state level are barriers to effectively enacting the building energy code in the states (i.e. state designated agencies) (AEEE, 2017).

Economic and Financial

Financial incentives for energy efficiency are typically included in the green building process for new buildings. This discourages the ambition to achieve higher energy efficiency by only meeting the minimum mandatory energy efficiency criteria of the green building rating system (Das, 2022).

Capacity

Currently, BEE offers capacity building programmes for building energy auditors and training for building energy code compliance. In addition, various organisations offer several capacity building programmes on green and energy efficient buildings for architects, students, professionals and government staff. However, the local authorities (ULBs) responsible for implementation and enforcement need further capacity building (AEEE, 2017).

Information

There are web portals to promote energy efficiency and renewable energy in buildings. For example, a web portal for NZEBs (nzeb.in, 2022); an information portal to disseminate information, solution sets and a compliance tool for the EcoNiwas Samhita (ECBC-R) (BEEP, 2022); However, reaching a wider domestic audience will require aggressive awareness and dissemination campaigns through various media.

6.5.2 Policy instruments for decarbonising India's building sector

Table 6 presents an overview of policy instruments in the India for decarbonising its building sector.

Table 6 An overview of policy instruments for decarbonising India's building sector

Policy instruments	Description

Governance & planning instruments	Policy roadmaps for building decarbonisation (including cooling/heating decarbonisation)	There is no roadmap for net zero buildings. The India Cooling Action Plan (ICAP) launched by the Ministry of Environment, Forest and Climate Change in 2019 aims to reduce cooling demand across sectors by 20% to 25% by 2037-38, (ii) reduce refrigerant demand by 25% to 30% by 2037-38, (iii) reduce cooling energy requirements by 25% to 40% by 2037-38. However, no specific targets for building envelope improvement are specified (Ozone Cell, MOEF&CC, 2019). The ICAP must be monitored and executed under the governance of a high-level inter-ministerial framework (Ministry of Environment, Forest & Climate Change, 2019).In December 2015, the Government of India launched the first phase of its grid-connected solar programme, a central rooftop solar subsidy programme. The programme's target was to achieve 40 GW of grid-connected rooftop solar in the country by 2022, divided into state-wise and year-wise targets (Kapoor, 2015). However, the target was not met, and the programme was further extended till 31 March 2026 (PIB, 2022).
	Pricing mechanisms	India does not have an explicit carbon pricing policy. However, an implicit form of carbon pricing in the form of fuel excise taxes covers 54.7% of emissions in 2021. The net effective carbon rate (ECR) is zero or negative in buildings (OECD, 2022).
	Energy Efficiency Obligations	The Energy Conservation Act identifies energy-intensive sectors (mainly industry and railways) as Designated Consumers (DCs). Under PAT Cycle VI, which started on 1 April 2020, commercial buildings (hotels) have also been added to the list of DCs. DCs must conduct a mandatory energy audit by an accredited energy auditor in the prescribed manner and interval. The audit should also include recommendations to improve energy efficiency and save energy. In addition, under the Perform Achieve and Trade (PAT) scheme, the energy savings achieved by the DC can be traded using Energy Saving Certificates (ESCerts) issued by BEE (BEE, 2023d).
	Energy Efficiency Funds	The State Energy Conservation Fund (SECF) is an instrument to overcome the significant impediments to implementing energy efficiency projects. The scheme was open to all states/UTs with a maximum ceiling of INR. 4 crore (INR 400 million) for each state/UT, to be released in two tranches of INR 2 crore each (BEE, 2019). Under the Framework for Energy Efficient Economic Development (FEEED) initiative, two funds have been created. Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE) and Venture Capital Fund for Energy Efficiency (VCFEE). PRGFEE provides a risk sharing mechanism to mitigate the risk for commercial banks lending to energy efficiency projects. The guarantee limit is INR 30 million per project or 50% of the loan amount, whichever is lower. Government buildings, municipalities, SMEs and industries will be supported under this initiative. VCFEE provides equity capital for energy efficiency projects up to INR 20 million per project or a maximum of 15% of the total equity required, whichever is less. Support under VCFEE is restricted to government buildings and municipalities (Ministry of Power, 2016).
	Removing subsidies for fossil fuel	Universal subsidy for cooking gas (LPG) was removed and the subsidy was restricted to targeted beneficiaries (Aadil et al., 2020). India imposed a cess on domestically produced and imported coal and set up the National Clean Energy and Environment Fund (NCEEF) in 2010.The coal cess is levied on the dispatch of

		coal and lignite by coal producers and discourages coal consumption by increasing its cost. For this reason, India's Intended Nationally Determined Contribution (INDC) further specifies that "the coal cess translates into a carbon tax equivalent" With the introduction of the Goods and Service Tax (GST) in India in July 2017, the Clean Energy Cess was abolished by the Taxation Laws Amendment Act, 2017. A new cess on coal production, called the GST Compensation Cess, was implemented at the same rate of INR 400 per tonne. A bigger share of the Clean Energy Cess receipts have not been sufficiently used to promote RE technologies (IISD et al., n.d.)
	Presence of a dedicated political body	At the national level, the Bureau of Energy Efficiency (BEE) develops and implements policies to increase energy efficiency, including in the building sector (BEE, 2023a). At the state level, there are State Designated Agencies (SDAs), which undertake energy efficiency activities with BEE and act as nodal agencies at the state level (BEE, 2019).
Regulatory instruments	Building energy code	There are building energy codes for both commercial and residential buildings - Energy Conservation Building Code (ECBC) 2017 for commercial buildings and Eco Niwas Samhita, Part - I & II (Energy Conservation Building Code for Residential Sector) (BEE, 2023c). In addition, the National Building Code (NBC) 2016 incorporates various aspects that promote sustainability in the built environment, with a dedicated chapter on the approach to sustainability (energy efficiency is usually implicitly considered under sustainability) (BIS, 2016).
	Product-specific minimum energy performance standards (MEPS)	Number of appliances with MEPS: 9 (Subramanian, Bastian, Hoffmeister, et al., 2022)
Economic instruments	Financial incentives or Energy Saving Auction	Incentives are usually linked to green building certification or rating systems, such as IGBC-rated or GRIHA-rated green building projects. For example, the type of incentives depends on the minimum green building rating achieved, (GRIHA, 2022; IGBC, 2022): The Ministry of Urban Development issues a notification to local authorities to provide incentives and 1% to 5% additional floor area and floor area ratio (FAR) for projects of more than 3000 sqm plot size based on GRIHA rating. GRIHA certified 4- and 5-star projects would be eligible for financial incentives under Sunref India. Fast-track environmental clearances for green building projects provisionally or pre-certified by green building rating systems. The central government's Grid Connected Rooftop and Small Solar Power Plants scheme aims to install 4,200MW of RTS systems in residential buildings by 2019-20, of which 2,100MW should be achieved through Central Financial Assistance (CFA) to building owners and implemented/facilitated by distribution utilities/companies (DISCOMS) (MNRE, 2019). Under the scheme, a subsidy of 40% will be provided for installing systems of less than 3 kW and 20% for rooftop solar systems of 3 kW to 10 kW. The Union Government launched Pradhan Mantri Ujjwala Yojana" (PMUY) on 1st May 2016. The PMUY scheme provides LPG connections to households living below the poverty line. It was originally launched in 2016 to provide 50 million LPG connections by 2019. Total budget allocation of INR 8 billion was made over three years starting from FY 2016-17. The scheme

		provides a financial support of INR 1,600 for each LPG connection to the eligible BPL households (PMUY, 2021). This target was later increased to 80 million connections by 2020, and was achieved ahead of schedule. Once a household has an LPG connection, it receives a subsidy through the Direct Benefit Transfer of LPG scheme, also known as PAHAL. Every residential consumer in India is eligible for this subsidy, subject to conditions (MOPNG, 2023).
Promoting business models and financing	Policies promoting energy services-ESCOs	BEE, in collaboration with CRISIL, provides a rating voluntarily to BEE empanelled ESCOs. This rating helps ESCOs to gain visibility and credibility (Bureau of Energy Efficiency, 2022). EESL is a joint venture of four public sector companies of the Ministry of Power, Govt. of India, with a net worth of over $32 billion (Jindal, 2018). It has been implementing the Building Energy Efficiency Programme (BEEP) for the retrofitting and energy efficiency of commercial buildings in India (EESL, 2022c). To date, 11,000 buildings have been included in the programme, investments of INR 3.5 billion have been made and the programme is being scaled up. Key areas of intervention/retrofitting include lighting and LED lighting, EE fans and super-efficient air conditioners (EESL, 201 C.E.). EESL has pioneered the installation of smart meters using the BOOT (build, own, operate, transfer) model, which avoids up-front investment by states/utilities (EESL, 2022d). Through EESL's Super-Efficient AC Programme (ESEAP) programme in two phases, EESL used a bulk procurement route through competitive sealed bidding method to promote super-efficient ACs. 150,000 units were procured and sold through the ESCO and DSM routes through DISCOMS (Bhargava & Singh, 2021). BEE carries out capacity Building of DISCOMs to implement DSM activities in their respective areas, including training DISCOM officials in DSM and EE activities, conducting load research studies, supporting states in the notification of DSM regulations (BEE, 2023b).
	Policy promoting One-Stop-Shops (OSS)	EESL is a super ESCO and can be regarded as an OSS.
	Financing instruments	Dedicated line of credit (soft loan) or refinancing of projects with limited budget and timeframe by bilateral/multilateral agencies: Sunref India affordable green housing for green buildings (Sunref India, 2022); and KfW Bank refinancing programme for energy efficient housing (now defunct) (Auswärtiges Amt, 2022). On-bill financing: Domestic Efficient Lighting Programme (DELP), implemented by DISCOMS in partnership with EESL, where LED lamps were given to consumers and the cost was recovered through monthly electricity bills in small instalments (EESL, 2022a). India is estimated to have the second largest green bond market, with bonds worth USD 7.2 billion (Bhaskar et al., 2021). The Securities and Exchange Board of India (SEBI) has issued final guidelines for issuing and listing Green Bonds for various sustainable projects, including energy efficiency projects, efficient and green buildings, etc. (SEBI, 2022a, 2022b).
Information instruments	Building rating and disclosure policies	The Energy Efficient Housing Programme (NHB) (now defunct) facilitated refinancing for energy-efficient high-rise buildings. Qualification for the scheme was based on an Energy Performance Certificate (EPC) (Auswärtiges Amt, 2022). This was one of the first pilot programmes for residential EPCs.

		BEE promotes a voluntary star rating system for commercial buildings (offices, BPOs, hospitals and shopping centres) (BEE, 2022a). Shunya (Zero) Labelling Programme for Net Zero and Net Positive Energy Buildings was launched on national energy conservation day on 14th December 2021 (Ministry of Power, GOI, 2022).
	Mandatory Energy labelling schemes of products	Appliance groups covered:7; Mandatory, Categorical (Subramanian, Bastian, Hoffmeister, et al., 2022)
	Provision of information	Information portal for dissemination, solution sets, and compliance tool for ECBC-R (BEEP, 2022). National portal for solar rooftop provides information on procuring solar rooftop and current government financial incentives (MNRE, 2022). The nzeb.in information portal, developed under a bilateral initiative between India and the US, supports mainstreaming energy efficiency and net zero energy buildings through dissemination, knowledge sharing and capacity building of various stakeholders (nzeb.in, 2022). Web portals for information exchange and opportunities for market integration, transformation, and mainstreaming energy efficiency (MAITREE) (MAITREE, 2022).
	Policies supporting targeted energy advice	No
R&D policies	R&D policies foster innovations	BEE facilitates the National Energy Efficiency Roadmap for Movement towards Affordable and Natural habitat (NEERMAN) Awards. This award facilitates national-level recognition for exemplary building designs complying with BEE's Energy Conservation Building Codes (BEE & Ministry of Power, GOI, 2022). BEE facilitates the National Energy Conservation Awards (NECA) to recognise energy efficiency in various energy-intensive sectors, including the building sector (BEE, 2022c). The Department of Science and Technology (DST) supports R&D activities to improve the energy performance of buildings and cities through various research programmes/grants/awards (DST, 2022).
Policies supporting capacity building	Training and education: Certification of qualified actors	ICAP aims to train and certify 100,000 service sector technicians in cooling and related areas by 2022-23, in synergy with the Skill India Mission (Ozone Cell, MOEF&CC, 2019). National Institute of Solar Energy (NISE) organises Suryamitra Skill Development Programme to train youth in installing, operating, and maintaining renewable solar energy technologies (NISE, 2022). Under the UNDP GEF BEE project, BEE has trained ECBC Master Trainers who are qualified to train architects, engineers, third party verifiers and ECBC enforcement officers to ensure compliance with the ECBC (BEE, 2022b). BEE conducts national level examinations for certified energy managers and energy auditors (BEE & NPC, 2022).
Lead by example	Lead by example	The Government of India is promoting the implementation of energy efficiency retrofits in its various buildings under the BEEP programme, facilitated by EESL. Under this programme,

		energy efficiency retrofits have been carried out in buildings of various ministries and railway stations (EESL, 2022b). The Ministry of Environment, Forestry and Climate Change is housed in an exemplary nZEB with features such as 100% on-site renewable energy generation, through-air conditioning, screw chillers with geothermal heat exchange and a chilled beam system (MOEF&CC, 2022). The Ministry of New and Renewable Energy has launched a Special Area Demonstration Project Scheme to demonstrate renewable energy options in places of national pride and of national and international importance, including heritage sites. Many states have implemented such demonstration projects in various buildings (HAREDA, 2022).

6.6 Indonesia

6.6.1 Major barriers and drivers to sectoral decarbonisation in Indonesia

Structural

- The rapid urbanisation in Indonesia is the primary driver of growing energy demand in the building sector. Indonesia's urban population is expected to increase by 100 million over the next 40 years, reaching an urbanisation rate of nearly 80% by 2060 (IEA, 2022a).
- Indonesia has made considerable progress in improving energy access; compared to 67% in 2010, today, approximately 100% of the country's population has access to electricity, adding 110 million electricity users (IEA, 2022a).
- The ownership of appliances and equipment is growing in parallel to the rising income of households, driving a strong increase in energy consumption in buildings (IEA, 2022a). Air conditioner purchases are expected to increase by 0.4 units per household in 2030 and by almost two units per household in 2060 (IEA, 2022a).
- As a result of an increase in average gross national income and GDP per household, Indonesians tend to live in larger houses and smaller families (IEA, 2022a). The average floor area of 100 m^2 is expected to rise to 112 m^2 by 2030, then to 155 m^2 by 2060 (IEA, 2022a).

Political

- There is no roadmap for building decarbonisation.
- The legal regulations regarding constructing low carbon and climate-resilient buildings are insufficient (Danish Energy Agency, 2022).
- The lack of monitoring and enforcement results in poor compliance with energy efficiency standards and regulations (Danish Energy Agency, 2022).
- The electricity rate is low in Indonesia and ranks lowest in Southeast Asia (Mariska, n.d.).

Economic

- In Indonesia, capital mobilisation for energy efficiency is hindered by high upfront costs and a lack of access to affordable financing (ADB, 2021; IEA, 2022a).
- As a result of limited public financing, there are few financial incentives for energy efficient buildings and investment in low carbon technologies (Danish Energy Agency, 2022).

Capacity

Energy efficient building construction and renovation in Indonesia face significant capacity challenges due to the shortage of skilled workforces, the limited experience and knowledge of construction professionals in planning and developing energy efficiency construction projects(Danish Energy Agency, 2022).

Information

There is a lack of awareness of stakeholders regarding energy efficiency projects and opportunities (Danish Energy Agency, 2022).

6.6.2 Policy instruments for decarbonising Indonesia's building sector

Table 6 presents an overview of policy instruments in the India for decarbonising its building sector.

Table 6 An overview of policy instruments for decarbonising India's building sector

Policy instruments		Description
Governance & planning instruments	Policy roadmaps for building decarbonisation	The Danish Energy Agency developed a roadmap based on the GlobalABC roadmap framework in close cooperation with the Indonesian Ministry of Energy and Mineral Resources. However, no legally binding targets for energy savings and net-zero buildings exist (Danish Energy Agency, 2022).
	Pricing mechanisms	Until now, there has been no carbon pricing in Indonesia. *Presidential Regulation No. 98* was issued in 2021 on the Implementation of Carbon Pricing to Achieve the Nationally Determined Contribution Target and Control over Greenhouse Gas Emissions in National Development. The government planned to implement it on April 1, 2022 (Wedari, 2022).
	Energy Efficiency Obligations	No
	Energy efficiency funds	No
	Removing subsidies for fossil fuel	Indonesia has gradually removed its fossil fuel subsidies (FuturePolicy.org, n.d.) by eliminating the gasoline subsidies and implementing a fixed diesel subsidy as of 2015 (ADB, 2015). However, the subsidies for electricity and other petroleum fuels remained (Climate Scorecard, 2018).

		As a response to rising energy prices and reducing their impacts on low-income households, the government has offered cash transfers, raised spendings on social programmes and exempted certain industries and agricultural sectors from taxes (ADB, 2015)
	Phasing out fossil fuel boilers	Not relevant
	Presence of a dedicated political body	The Ministry of Public Works and Housing (MPWH) and the Ministry of Energy and Mineral Resources (MEMR) are responsible for energy efficiency measures (Danish Energy Agency, 2022). While MEMR controls most of these measures, the MPWH administers the building and residential sectors and works on the national green building guidelines (Danish Energy Agency, 2022). The energy efficiency components of standards and regulations for green buildings are developed by MEMR (Danish Energy Agency, 2022).
Regulatory instruments	Building energy code	The Government Regulation No. 36/2005 on Buildings mandates new buildings to implement energy conservation measures, including residential buildings of more than 500 m^2 and commercial buildings of more than 5,000 m^2 to meet minimum energy performance requirements (Danish Energy Agency, 2022). However, this law has not been strictly enforced (Danish Energy Agency, 2022). Almost all existing buildings do not comply with building energy codes, except buildings constructed to meet green building codes in large cities (e.g., Jakarta, Bandung and Semarang). Green building codes have been implemented in Jakarta since 2013 with the International Finance Cooperation (IFC) support (Danish Energy Agency, 2022). The code includes Minimum Energy Performance standards (MEPS). However, using the green building codes only applies to buildings larger than 50,000 $m^{2,}$ and the number of such new buildings is limited (Danish Energy Agency, 2022). Data regarding energy consumption and building stock in Indonesia is limited for monitoring purposes (Danish Energy Agency, 2022).
	Product-specific minimum energy performance standards (MEPS)	The government promulgated and enacted the R*egulation of the Minister of Energy and Mineral Resources No. 14/202*1 on the Application of Minimum Energy Performance Standards to Energy Consuming Equipment (hereinafter the "Regulation"). The Regulation sets out the fundamental principles for the minimum energy performance standards (MEPS) and energy efficiency labelling scheme for energy-consuming equipment. Detailed rules are first established for compact fluorescent lamps and air conditioners. On October 3, 2022, the Ministry of Energy and Mineral Resources of Indonesia notified WTO/TBT of draft decrees on the MEPS for blenders, drinking water dispensers, electric stoves, washing machines, smoothing irons, televisions, electric motors and water pumps. (Kenji, 2021)
Economic instruments	Financial incentives Energy Saving Auction	There is generally a lack of economic incentives (Danish Energy Agency, 2022).
Promoting business	Policies promoting energy services- ESCOs	Ministerial Regulation No. 14/2016 legally defined the ESCO to facilitate the implementation of energy effi-

models& financing		ciency projects. This regulation gives a detailed description of ESCOs' activities, including planning, financing and monitoring of energy efficiency projects, monitoring and maintenance of energy installation and construction work, and conducting investment-grade energy audits (Danish Energy Agency, 2022).
	Policy promoting One-Stop-Shop	No
	Financing instruments	No
Information Instruments	Building rating and disclosure policies	No
	Energy labelling schemes of products	2 types of products, Mandatory Categorical (Subramanian, Bastian, Hoffmeister, et al., 2022)
	Policies supporting targeted energy advice	No
RD&D policies	RD&D policies foster innovations	No
Policies supporting capacity building	Training and education: Training programs for local governments on requirements and compliance Training and certificate programs for building inspectors Sponsored university degree programs on building energy efficiency	No
	Certification of qualified actors	The Indonesian National Work Competency Standard (SKKNI) includes characteristics of knowledge, skills, and/or expertise, and work attitudes, that are important to the execution of assigned responsibilities and job requirements. Below are the SKKNI on energy: SKKNI 2018-053 Energy Audit SKKNI 2015-080 Energy Manager SKKNI 2020-223 Energy Monitoring and Verification (Danish Energy Agency, 2022).
Lead by example		There is no specific focus on energy-efficient public buildings or procurement (Danish Energy Agency, 2022).

6.7 South Africa

6.7.1 Major barriers and drivers to sectoral decarbonisation in South Africa

Structural

- The population of South Africa is expected to grow by 27% by 2050, as well as become more urbanised (Climate Transparency, 2022), which results in the growth of energy consumption.

- In South Africa, half of the population is poor to very poor and nearly a quarter lives in informal settlements in urban areas (Euston-Brown & George, 2021). Economic stagnation with poverty and the vast number of informal settlements in urban areas has driven a fundamental change to NZC buildings (Euston-Brown & George, 2021).
- Rapid building stock increase in cities
  A rapid expansion of building floor areas has been observed in South African cities. The building stock had grown by around 2 million m^2 to almost 20 million m^2 between 2011 to 2017 (Cilliers & Euston-Brown, 2018).

Political

- Subsidies for fossil fuels, primarily used for supporting the production and consumption of petroleum and coal in South Africa, have fluctuated significantly between 2010 and 2019 and reached USD 4.3 billion in 2019 after increasing dramatically (Climate Transparency, 2021b).

- **Politics**
  Complexity due to detailed regulations at the national level with the share of responsibilities between different national and local public bodies; Different approaches and rules applied by different cities.
  In South Africa, the national building regulations are highly detailed, and there is a dispute over the share of responsibilities between national and local levels (Euston-Brown & George, 2021). There is no uniformity in the building practice, and the enforcement at the local level varies significantly since the cities apply their approaches and rules (Euston-Brown & George, 2021).

Economic and Financial

- South African developers are considering the actual cost of zero buildings as the major barrier to developing net zero buildings (Terblanche, 2019).
- Split incentives are a barrier to investment in energy efficiency upgrades in the rental sector (Department of Energy et al., 2018).
- There is still a long way to go for South Africa's ESCO industry to achieve its potential (IDC, 2018). Many ESCOs have difficulty to raise capital for their projects due to the absence of financial instruments designed for the ESCO industry (IDC, 2018). In addition to the financing, informational and awareness gaps, the ESCO market has faced regulatory, procurement and technical challenges in South Africa. (Engineering News, 2021).
- The provision of formal housing and enforcement of existing local requirements to achieve net zero buildings are severely constrained by the local authorities' lack of funding and economic recession (Cilliers & Euston-Brown, 2018).

- In South Africa, Eskom electricity prices have rapidly increased, creating significant demand for low-cost alternative energy sources (GreenCape, 2022). Since 2007, the average Eskom tariffs have increased by 307% (GreenCape, 2022).

Capacity

- Decarbonising the building sector is hindered by the enormous capacity constraints in the building control departments and municipalities (Euston-Brown & George, 2021; SEA & SALGA, 2021).
- A knowledge gap exists in the South African construction industry regarding the benefits, implementation, and actual costs of sustainable and net zero buildings (Terblanche, 2019). In general, the lack of knowledge among professionals and contractors (Amoah & Smith, 2022), as well as the lack of skills in the public and private sectors, are considered barriers to the implementation of green measures in the building sector (Department of Energy et al., 2018).

Information

The lack of knowledge is not limited to professionals; homeowners consider themselves insufficiently informed about energy-efficiency measures (Amoah & Smith, 2022).

6.7.2 Policy instruments for decarbonising South Africa's building sector

Table 7 presents an overview of policy instruments in the South Africa for decarbonising its building sector.

Table 7 An overview of policy instruments for decarbonising South Africa's building sector

Policy instruments		Description
Governance & planning instruments	Policy roadmaps for building decarbonisation	South Africa's National Development Plan (issued in 2011) sets a goal for zero emissions buildings by 2030 (National Planning Commission, 2011). The Post-2015 National Energy Efficiency Strategy (NEES, issued in 2016) sets the following target compared to the 2015 level: Residential: reduction in the average specific energy consumption of new household appliances purchased, 30% improvement in the average performance of the residential building stock, 37% in the specific energy consumption reduction in the commercial sector; 50% energy consumption reduction in the public sector by 2030, (Department of Forestry, Fisheries and the Environment, 2021).
	Pricing mechanisms	İn 2019, SA introduced a carbon tax. The scheme covers the sources of about 80% of domestic emissions, including

		all types of fossil fuels used in industry, power, buildings, and transport sectors. The rate started from R120/ CO2e (currently less than US$8) per ton and was increased annually by inflation plus 2%. In 2022, the government increased the rate to R144 (about US$9). It was very low compared to international practice. It will increase yearly by at least US$1 until it reaches US$20. From 2026, the government intends to escalate the carbon price rapidly every year to reach at least US$30 by 2030 and US$120 by 2050 (Climate Transparency, 2021b). The revenue was used to create tax incentives for decarbonisation, e.g. tax incentives for energy efficiency projects (no quantitative info) (Momoniat, 2021).
	Energy Efficiency Obligations	Eskom is the largest producer of electricity in Africa, generating approximately 95% of the electricity usage in South Africa. In 2004, Eskom launched a national Energy Efficiency and Demand-Side Management programme, which ratepayers fund. İt was changed to Integrated Demand Management (IDM) Programme in 2010 and was implemented until 2013. İt has covered residential and commercial buildings and supported various technology interventions (Eskom, 2019). Due to financial constraints, many Eskom IDM programmes have been placed on hold (Department of Energy et al., 2018).
	Energy efficiency funds	The Green Energy Efficiency Fund was launched by the Industrial Development Corporation (IDC) in partnership with the German Development Bank (KfW) in 2011. The funding encourages investments in EE and renewable energy projects to support the transition towards a low-carbon economy. The Fund has been well-subscribed, but not enough projects have benefited. The Fund offers a long payback term of up to 15 years, easing companies' debt burden (Department of Energy et al., 2018; SME South Africa, 2022). The Fund continues to exist now.
	Energy and urban planning	Only demonstration; no potential analysis. The first solar district heating system in South Africa has been installed in the Wits Junction. The installation combines solar thermal collection with co-generation and gas heating technology and serves 14 student residences of more than 1 000 people from a centralised hot water plant room. This forms part of a more extensive programme of SOLTRAIN, which has built 326 solar thermal systems, saving about 2 000 megawatt-hours per year and avoiding 638 tonnes of CO2 (GlobalABC et al., 2020).
	Removing subsidies for fossil fuel	In 2010-2019, South Africa's fossil fuel subsidies fluctuated considerably, reaching a value of USD 4.3 billion in 2019. Most of them were used to support the production and consumption of petroleum and coal. Comparable data is not available yet for 2020. However, according to the Energy Policy Tracker data, in 2020, South Africa pledged at least USD 637m to fossil fuel energy as part of its energy-related funding commitments and COVID-19 economic response (Climate Transparency, 2021b).

	Presence of a dedicated political body	The South African National Energy Development Institute (SANEDI) was established in 2011 under the National Energy Act, 2008 (Act No. 34 of 2008). The Act allows SANEDI to direct, monitor and conduct energy research and development and promote energy research and technology innovation.
Regulatory instruments	Building energy code	Buildings are historically regulated by the National Building Regulations and Building Standards Act of 1977 (the Act). The National Bureau of Standards developed standards to implement the Act, i.e. SANS 10400. In 2011, a new part, SANS 10400XA, was added to regulate the maximum allowable energy consumption for all new buildings and the significant extension of existing buildings (only the extension will have to comply with the regulations. (Sustainability Institute & Nedbank, n.d.). Both residential and commercial buildings are targeted (Swift, 2013). SANS 10400-XA offers certain flexibility to building owners or architects on how to achieve energy performance requirements. Compliance with SANS 10400-XA is monitored by local building authorities, who can issue fines for non-compliance. (bigEE, n.d.-b). Successive tightening of the building energy codes contributes significantly to achieving the targets in the NEES. The NEES entailed a revision every five years to gradually take the market to more stringent levels (Boshoff & Mey, 2020; Building & Decor, 2017).
	Product-specific minimum energy performance standards (MEPS)	15 appliances with MEPs (Subramanian, Bastian, Hoffmeister, et al., 2022) Conformity: Manufacturers and importers must have a Letter of Authority (LOA) issued by the National Regulator for Compulsory Specifications (NRCS) before an appliance can be sold in South Africa. The LOA verifies that the particular appliance conforms to the Minimum Energy Performance Standards (MEPS) specified for that category. LOAs are valid for three years (Department of Mineral Resources and Energy, n.d.-b).
	Phasing out fossil fuel boilers	No
Economic instruments	Financial incentives or Energy Saving Auction	The 12L Tax incentive started in 2013 until now: It allows taxpayers to claim deductions of 95 cents per kWhe of EE savings, which are verified by accredited professionals (Deloitte, n.d.; Department of Energy et al., 2018). However, it only targeted larger users, typically commercial and industrial consumers. The Energy Efficiency Demand Side Management (EEDSM) programme (2009-now) supports municipalities in their efforts to reduce electricity consumption by optimising their use of energy. Selected municipalities receive grants for the planning and implementing energy-efficient technologies ranging from traffic and street lighting to energy efficiency in buildings and water service infrastructure. (Department of Mineral Resources and Energy, n.d.-a). Since its start in 2009, significant funding (over R1 billion) has been dedicated towards the programme, and 54 municipalities have participated (inno4sd, 2019). SA does not have appropriate schemes to incentivise banks to provide soft loans with longer payback periods (Department of Mineral Resources and Energy, n.d.-c).

Promoting business models& financing	Policies promoting energy services- ESCOs	Although South Africa's ESCO industry was formally established in 2002, the ESCO market is still far from tapping its full potential and is not developing into a vibrant, growing industry. It is dominated by only a few significant large ones and consists of many small players (about 400) (IDC, 2018).
	Policy promoting One-Stop-Shops	No
Information Instruments	Building rating and disclosure policies	The government released a regulation for mandatory energy performance certificates (EPCs) in 2020: SANS 1544 Energy Performance Certificate (Notice 700 of Government Gazette 43792 of 8 December 2020) It made EPC mandatory for: all commercial and non-residential buildings greater than 2000sqm; government buildings larger than 1000 sqm. (SANEDI, 2022) All buildings must comply with the regulation until the end of 2022. The South African Departments of Energy, Public Works and Environmental Affairs have developed a NAMA entitled Energy Efficiency in Public Buildings and Infrastructure Programme. Among others, it aims to support the introduction of EPC for public buildings and a reliable monitoring system to chart the improvements (NAMA Facility, n.d.). The Department of Mineral Resources and Energy is responsible for issuing EPC and monitoring compliance (SANEDI, 2022).
	Energy labelling schemes of products	16 groups of appliances with mandatory energy labelling Categorical (Subramanian, Bastian, Hoffmeister, et al., 2022)
	Policies supporting targeted energy advice	No
RD&D policies	RD&D policies foster innovations	No
Policies supporting capacity building	Training and education: Certification of qualified actors	Limited. For example, Eskom provides technical skills training and workshops, but further organised and systematic training is needed (Department of Energy et al., 2018).
Lead by example		The government aims to cut the specific energy consumption of public buildings in half by 2030, compared to 2015 levels (NAMA Facility, n.d.).

6.8 Japan

6.8.1 Major barriers and drivers to sectoral decarbonisation in Japan

Structural

The growth in building floor areas and the number of households have resulted in higher energy consumption (Arimura & Matsumoto, 2021). The number of households has increased by around 2.4 million to 56 million from 2015 to 2020.

Political

Since 2016, Japan, a part of G7, committed to phase out "inefficient" fossil fuel subsidies by 2025. However, Japan is still the second-largest supplier of fossil fuel public finance in the world, most of which are used for overseas oil and gas exploration activities and development projects (350.org, 2022; IEA, 2021a).

Economic and Financial

- Commercialisation and promotion of the ZEB are often hampered by its higher upfront cost, which is incurred as a result of higher prices for insulation, lighting and HVAC systems, as well as sometimes custom design and construction of buildings (Farabi-Asl et al., 2018)
- Despite Japan's successful financing mechanism for large companies, small and medium enterprises lack adequate access to attractive funding (Nurcahyanto & Urmee, 2018).

Capacity

There appears to be no barrier in terms of capacity at current low retrofit rates. New build benefits from the high share of prefabricated housing.

6.8.2 Policy instruments for decarbonising Japan's building sector

Table 8 **Fehler! Verweisquelle konnte nicht gefunden werden.** presents an overview of policy instruments in the Japan for decarbonising its building sector.

Table 8 An overview of policy instruments for decarbonising Japan's building sector

Policy instruments		Description
Governance & planning instruments	Policy roadmaps for building decarbonisation	Japan aims to reach net-zero energy consumption for new buildings (ZEBs) and houses (ZEHs) by 2030 and all buildings by 2050 (MLIT, 2022, as cited in CAT, 2022). However, in 2020, only 0.42% of newly constructed buildings were ZEBs, and 24% of new houses were ZEHs (METI; MOEJ, 2022; METI, 2022d as cited in CAT, 2022). By 2030, Japan intends to achieve 100% efficiency with LED lights, install 5.3 million residential fuel cells and equip 90% of houses with efficient water heaters. (METI, 2019b; as cited in (IEA, 2021d)).

		The 1.5°C compatible pathways would have direct emissions from the building sector falling by 34-48% from 2019 levels by 2030 and reaching net zero between 2040-2052 (Climate Analytics, 2022).
	Pricing mechanisms	Japan's carbon pricing mechanisms include a carbon tax and regional emission trading systems. Japan introduced a carbon tax in 2012. It is an add-on to the existing petroleum and coal tax and is levied on crude oil and oil products, natural gas, and coal. Tax revenue is recycled to reduce CO2 emissions from energy use. (UNFCCC, 2019; as cited in (IEA, 2021d)). However, Japan has one of the lowest carbon tax rates amongst OECD and G20 countries (Lewis, 2022). Two local ETS schemes exist in the Tokyo municipality (since 2010) and Saitama Province (since 2011), part of the Greater Tokyo area. Carbon credits can be traded between the two jurisdictions. Together, they cover CO2 emissions from fuels, heat and electricity consumption of about 1 550 commercial and public buildings (IEA, 2021d).
	Energy Efficiency Obligations	No
	Energy efficiency funds	No
	Removing subsidies for fossil fuel	Since 2016, Japan, a part of G7, committed to phase out "inefficient" fossil fuel subsidies by 2025. It is estimated that fossil fuel subsidies accounted for 0.2% of total tax revenue in 2018, which is lower than the OECD average of 0.7% (OECD, 2020b, as cited in IEA, 2021b). Most of these subsidies are used for overseas oil and gas exploration activities and development projects implemented by Japanese companies (IEA, 2021d).
	Presence of a dedicated political body	The Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) and the Ministry of Economy, Trade and Industry (METI) are responsible for building energy efficiency policies. A "Review Committee on Concept of Energy Conservation Measures for Residences and Buildings Achieving a Decarbonised Society" was formed, which consists of MLIT and Ministry of the Environment (ECCJ, 2022a). This Committee offers a platform for a wide range of discussions on initiatives and policy-making in residential and non-residential buildings for achieving a decarbonised society (ECCJ, 2022a).
Regulatory instruments	Building energy code	Target: large- and medium-sized commercial buildings; new buildings; mandatory In 2015, Japan passed the Building Energy Efficiency Act, which obliges new large buildings to meet energy efficiency standards. Mandatory standards were first implemented for new large-scale commercial buildings (with floor space greater than 2 000 m2) in 2017. For small- and medium-scale residential buildings, constructors only need to report on the energy-saving performance (IEA, 2021d).

		The government recently revised the Act, which was enacted in June 2022. It requires new houses and buildings, including small-scale ones, to meet enhanced efficiency standards from 2025 onwards (CAT, 2022b). This is considered a significant improvement (Thomas, Adisorn, et al., 2021). It is necessary to obtain a building permit before the construction of a building commences to ensure that the plans comply with the Building Standard Law and other standards (Thomas, Adisorn, et al., 2021). Before occupancy, compliance with the energy efficiency requirements and structural safety regulations are monitored together (Thomas et al., 2021). The government may publish property owners' names, withhold construction and occupancy permits, and/or place a fine if they fail to comply with the standards. Monitoring of overall policy implementation: DECC for commercial buildings
	Phasing out fossil fuel boilers	Cooking and heating in new residential buildings are entirely electrified. However, existing buildings either use 'city gas/natural gas', 'LPG', and kerosene (Selectra, n.d.; Thomas, Adisorn, et al., 2021). The targets of ZEBs imply that these fossil fuels would need to be phased out in new buildings, and eventually also in the existing stock, but no specific regulation exists..
	Product-specific minimum energy performance standards (MEPS)	24 appliances with MEPS To improve appliance efficiency, Japan has implemented the Top Runner Program, which sets maximum values based on the most energy-efficient technology available on the market. Companies must meet these requirements for three to ten years, depending on the appliance's features. This Program has significantly increased energy efficiency of appliances. For instance, the efficiency of air conditioners increased by 28% from 2016 to 2021 (METI, 2018; as cited in IEA, 2021b). Wall-mounted models are expected to increase further by 34.7% compared to the current standards by 2027 (ECCJ, 2022a; METI, 2022).
Economic instruments	Financial incentives or Energy Saving Auction	For new construction, by the end of 2018, there were 70 ZEBs and 56000 ZEHs, representing 1% and 13% of the total number of buildings/houses, respectively (IEA, 2021d). Japan also offers subsidies for renovations and refurbishments of existing buildings. However, there is no comprehensive strategy in place (IEA, 2021d) Following the revision of the Building Energy Efficiency Act, the Japan Housing Finance introduced *low-interest financing* to improve the energy efficiency in existing residential and non-residential buildings (ECCJ, 2022b). No rebates for appliances as energy efficient appliances are mainstream. Tax: Japan introduced new tax incentives for promoting energy efficiency in May 2018. Economic operators classified as energy efficiency operators can

		benefit from accelerated depreciation (30%) of their investments in energy efficiency (IEA, 2019d).
Promoting business models& financing	Policies promoting energy services- ESCOs	In Japan, ESCOs are clearly defined in the law, but the definition is inadequate. There is no ESCO accreditation scheme. Standard contracts exist but are too complex (Canu et al., 2022).
	Policy promoting One-Stop-Shops	No; but government develops licensed support centres for the retrofit, where consumers can receive a free consultation and the work plan quotation check.
Information Instruments	Building rating and disclosure policies	According to the Buildings Energy Efficiency Act, all new constructions and retrofits may be certified if they conform to specific efficiency standards. The certificate may bring some benefits, e.g., less restriction on building size (IEA, 2021d). However, this certification is not mandatory.
	Energy labelling schemes of products	The *energy-saving labelling system* has been introduced to inform consumers about energy efficiency and to promote energy-efficient products. It covers the following 18 Top Runner products: air conditioners, refrigerators, TV sets, freezers, fluorescent lights, electric toilet seats, electric rice cookers, microwave ovens, DVD recorders, gas cooking appliances, gas water heaters, oil water heaters, computers, magnetic disk units, gas/oil space heaters, transformers, routers, and switching units. The labelling is voluntary and categorical (APEC EGEE&C, 2012), which means that it does not require comparing a product's energy consumption with those of other products (ECCJ, 2018). The 2005 revision of the Energy Conservation Act introduced new and reinforced labelling provisions for appliances. It is mandatory for retailers and contains a rating (stars), energy saving labelling system, and information on expected electricity costs. The new comparative rating system is presented as a five-star rating and provides consumers with the necessary information to compare products in the same category. As of October 2021, the label is required for nine designated products: air conditioners, electric refrigerators and freezers, electric toilet seats, TV sets, LED lights and water heaters using electricity, gas and oil (IEA, 2021l).
	Policies supporting targeted energy advice	No
RD&D policies	RD&D policies foster innovations	To achieve its ZEB targets for new buildings, the government has developed demonstration projects, e.g., applying high-performance building materials and equipment to reach ZEB. (Agency for Natural Resources and Energy & METI, n.d.)

Policies supporting capacity building	Training and education: Certification of qualified actors	No The Energy Conservation Center (ECCJ), associated with METI, provides energy efficiency certification. There are three main types of certificates. The first one is the certificate given to professionals, including engineers and supervisors, after they attend lectures, take a written exam, and prepare a report. The second certificate is given to professional energy auditors after they take an exam and provide an actual audit. The third certificate is issued to energy conservation experts when they pass the exam (ECCJ, n.d.). However, no info is found on sponsored university degree programs on building energy efficiency.
Lead by example		No

6.9 Turkey

6.9.1 Major barriers and drivers to sectoral decarbonisation in Turkey

Structure:

- Rapid economic and population growth in the past two decades has driven strong energy demand growth. The already high energy consumption is expected to grow further, driven by continued population growth and urbanisation (IEA, 2021g).
- The urbanisation rate in Turkey has reached 2% per year, which leads to a fast-growing building stock with new construction rates of more than 4%. (GIZ & Republic of Turkey Ministry of Environment and Urbanisation, 2019);
- Urban renewal would result in approximately 7 million residential buildings being retrofitted (GIZ & Republic of Turkey Ministry of Environment and Urbanisation, 2019), which presents a unique opportunity for decarbonising the building stock (Climate Action Tracker, 2022c). However, the current primary objective of urban renewal is to demolish existing buildings and rebuild to enhance resilience to natural disasters. (SHURA & BPIE, 2019).

Political

- No roadmap for net zero building in place.
- Turkey's government has subsidised energy prices to end users to support economic growth and public welfare (Acar et al., 2020b). Low energy prices are considered a significant barrier to energy efficiency investment.

Politics

- No dedicated national energy efficiency agency

- Unclear roles, responsibilities and authorities to enforce building energy code;

  Turkey's building energy code has not been strictly enforced due to the lack of clearly identified roles, responsibilities, and public bodies (SHURA & BPIE, 2019).

Economic and Financial

- The high upfront investment is required for the energy efficient technologies in buildings (GIZ & Ministry of Environment and Urbanisation, 2019). The economic situation of most households does not motivate them to invest in energy efficiency (IEA, 2021g).
- Turkey has a small ESCO market. Around 70% of the ESCOs are based in Istanbul, and the rest are spread throughout eight other cities (GIZ & Ministry of Environment and Urbanisation, 2019). Turkey's ESCO market is underdeveloped due to several reasons, including the lack of adoption of energy performance contracting in the public procurement process, the absence of sustainable financing models, the limited capacity of ESCOs and their inadequate access to finance, unknown risks associated with energy efficiency investments, and insufficient capacity of the actors involved (WB, 2019a).
- Energy efficiency financing in public buildings in Turkey is still limited as the budget of the government building administrators is insufficient for costly capital upgrades (WB, 2019a).

Capacity

- The lack of capacity of the relevant public authorities is considered a significant obstacle to enforcing mandatory building energy codes in Turkey (SHURA & BPIE, 2019).
- The construction industry lacks the knowledge and capacity to conduct and review energy audits, choose feasible energy efficiency measures, evaluate the quality of the designs, as well as implement energy efficiency projects (WB, 2019a).

Information

- Limited public awareness and insufficient knowledge of non-technical individuals regarding the low-cost energy efficiency improvements (GIZ & Ministry of Environment and Urbanisation, 2019; SHURA & BPIE, 2019) and energy labelling schemes, which promote high energy efficiency products, systems, and equipment (GIZ & Ministry of Environment and Urbanisation, 2019; Kama & Kaplan, 2013), are considered significant barriers to improve energy efficiency in buildings.
- It is also challenging for non-experts to accurately compare energy-efficient equipment/systems in terms of quality, performance, and cost (SHURA & BPIE, 2019).
- The suppliers of energy efficient technologies are often the only ones deciding on the efficiency and installed capacity of the equipment/system to be installed, based primarily on the upfront costs (SHURA & BPIE, 2019).

6.9.2 Policy instruments for decarbonising Turkey's building sector

Table 9 presents an overview of policy instruments in the Turkey for decarbonising its building sector.

Table 9 An overview of policy instruments for decarbonising Turkey's building sector

Policy instruments		Contents
Governance & planning instruments	Policy roadmaps for building decarbonisation	While there is no long-term roadmap for the building sector to reach net zero , Turkey's National Energy Efficiency Action Plan (2017-2023), announced in 2018, aims to "transform at least one-fourth of the building stock in 2010 to sustainable buildings by 2023 (Climate Action Tracker, 2022c).
	Pricing mechanisms	Fuel excise taxes, an implicit form of carbon pricing, have been implemented in Turkey. Effective carbon rates on buildings: less than 10 EUR/ ton CO2 (OECD, n.d.-a)
	Energy Efficiency Obligations	Turkish Government acknowledges that EEOs could be a proper mechanism for Turkey to achieve its energy efficiency targets. EEOs are explicitly mentioned in NEEAP: "It is expected to impose energy efficiency obligations on energy (electricity, natural gas, petroleum) distribution and/or retail companies, and the obligated parties will implement energy efficiency measures." However, it has not yet been implemented
	Energy efficiency funds	No
	Removing subsidies for fossil fuel	Annually USD 6.8 billion USD of government support to fossil fuels (2017–2019 average) (Picciariello, 2020)
	Phasing out fossil fuel boilers	No
	Presence of a dedicated political body	No agency predominantly focuses on energy efficiency. It is expected that the newly established Department of Energy Efficiency and Environment could potentially fill in the gap (SHURA & BPIE, 2019)
Regulatory instruments	Building energy code	Regulation on Energy Performance for Buildings / Binalarda Enerji Performansı Yönetmeliği (BEP): New buildings are required to comply with TS 825 since it became mandatory in 2000 and has been amended twice in 2008 and 2013 (SHURA & BPIE, 2019). TS 825 is now under the Regulation on Energy Performance for Buildings (BEP), which was adopted in 2008. The BEP sets minimum energy performance standards for buildings to be constructed and renovated (IEA, 2021g). The building energy codes above cover new and existing residential and commercial buildings (Subramanian, Bastian, Jennings, et al., 2022). In case of non-compliance, construction and occupancy permits are withheld (Delgado et al., 2021).

		There is no database of building energy performance.
	Product-specific minimum energy performance standards (MEPS)	Number of appliances with MEPS: 20 Mandatory (Subramanian, Bastian, Jennings, et al., 2022)
Economic instruments	Financial incentives	Heat Insulation Loan Package has become effective as of June 2022 (Hürriyet, 2022). It offers financing up to 50,000 Turkish Liras per dwelling at a 0.99 interest rate with a 60-month maturity (Hürriyet, 2022). Before the heat insulation loan package was announced for residential buildings, some banks provided heat insulation loans such as Individual Energy Efficiency Loan (Ziraatbank, n.d.). In 2018, tax laws were amended to encourage the renovation of existing commercial buildings, where insulation and energy-saving measures can be deducted in the year they are implemented (IEA, 2021g). A VAT and special consumption tax reduction was introduced for energy efficient home appliances in 2018; both tax reductions ended in June 2019 (U4E, 2017). The net metering scheme for rooftop solar PV allows homeowners to offset their electricity bills by getting a monthly credit for electricity exported to the grid (Flora et al., 2019).
Promoting business models& financing	Policies promoting energy services- ESCOs	ESCO activity in Turkey resumed the Energy Efficiency Law (EEL) in 2007 (GIZ & Ministry of Environment and Urbanisation, 2019). ESCOs must receive and renew their authorisation documents issued by the state to operate in Turkey (GIZ & Ministry of Environment and Urbanisation, 2019). In 2018, the amendment of the Energy Efficiency Law made it possible for the public sector to take part in energy performance contracts with ESCOs (IEA, 2019c). There is a lack of energy performance contracting in the public procurement process (WB, 2019a). The central government signed the first performance-based ESCO contract for energy efficient retrofit of a school in March 2021 (WB, 2021b).
	Policy promoting One-Stop-Shop	No
	Financing instruments	A total of US$ 350 million had been provided to four local banks by Turkish Residential Energy Efficiency Financing Facility (TuREEFF) (GEFF, 2022; Rosca, 2019). The consumer loans that incentivise building insulation and the financing provided by the development finance institutions are the primary sources of energy efficiency financing provided by the local banks (SHURA, 2019). Besides external funding sources, such as EBRD, WB and TurREEFF, consumers have access to consumer credits such as Işbank Environmentalist Credit to be used for heating and/or water isolation, natural gas transformation, energy saving heating/cooling systems' implementation etc. (Altun et al., 2016; Isbank, n.d.).

Information Instruments	Building rating and disclosure policies	Since 2011, new buildings and buildings for lease and purchase have been required to have EPC (IEA, 2021g). New buildings must have at least C class, while existing buildings do not need to meet any minimum threshold (IEA, 2021), covering all building types. EPCs are valid from the date of issue (EKB, n.d.). The number of buildings with an EPC reached almost 1 million by November 2019 (IEA, 2021). Buildings are checked before occupancy for their Energy Performance Certificates.
	Energy labelling schemes of products	As a part of efforts to comply with EU legislation, the product performance standards of Turkey are largely harmonised with EU Eco-design Directive 2009/125/EC and the Energy Labelling Framework Directive 2010/30/EU (IEA, 2021). New studies for the legislative harmonisation of energy labelling and eco-design will commence in 2021 (IEA, 2021).
	Information provision	Public awareness campaigns are conducted to increase awareness of energy efficiency and renewable energy technologies. Construction of a building model showing the energy efficiency and renewable energy technologies to raise awareness of the general public (GIZ, 2019) and public awareness campaign to increase demand for energy efficient buildings and promote behaviour change through TV sports, billboards (Bayraktar & Stewart, 2019) are two examples of the provision of information to the general public.
	Policies supporting targeted energy advice	No
RD&D policies	RD&D policies foster innovations	No
Policies supporting capacity building	Training and education: Training programs for local governments on requirements and compliance Training and certificate programs for building inspectors Sponsored university degree programs on building energy efficiency	There are guidelines prepared to inform decision-makers and actors regarding the energy efficient solutions and energy efficiency market, such as a guideline on retrofit for energy efficiency of Public Buildings (Ministry of Environment and Urbanization, 2020) and Energy Efficiency Technology Atlas for the Turkish Building Sectors (GIZ & Ministry of Environment and Urbanisation, 2019). In addition, capacity building and training activities are conducted to increase knowledge on EPC (IMO, 2021) and energy efficient design, planning and construction of buildings (Eclareon, 2022).
	Certification of qualified actors	The Turkish government requires the certification of professionals issuing energy performance certificates and authorising institutions providing energy manager training (Mevzuat Bilgi Sistemi, n.d.). There are also certification programs for energy companies and energy managers in building and industry sectors (AEE, 2022; Energy Charter Secretariat, 2014).
Lead by example		The Ministry of Environment and Urbanisation is implementing the Energy Efficiency in Public Buildings Project (KABEV) with the support of the Ministry of Energy and Natural Resources, with a budget of 200 million dollars provided by the World Bank

		(CEENERGYNEWS, 2021). As part of the Project, energy efficiency of 500-700 government buildings will be improved, and a national programme for energy efficiency in buildings will be developed (CEENERGYNEWS, 2021).

6.10 Mexico

6.10.1 Major barriers and drivers to sectoral decarbonisation in Mexico

Structural

- Mexico is the second-largest building market in Latin America (Mackres & Loutfi, 2020). The growing workforce and urbanisation rate have increased the building floor area in Mexico (Copenhagen Centre & Building Efficiency Accelerator, 2019). According to the government's estimates, over 600 million m2 of floor area will be added by 2030 due to the construction of around 15 million new units (PEEB, 2019a). The schools and non-residential buildings will also be expected to grow further by 2030. (PEEB, 2019a).
- In Mexico, increased appliance ownership, particularly from 2014 to 2018, resulted in higher energy consumption (IEA, 2021j). A significant increase in the demand for air conditioners is expected soon (IEA, 2017).

Political

- In 2019, USD 17.1 billion was spent on fossil fuel subsidies in Mexico (Climate Transparency, 2021, as cited in OECD-IEA, 2020). Petroleum received the most subsidies (USD 12.5 billion), followed by natural gas (USD 2.6 billion) and fossil-fuel-based electricity (USD 2 billion) (Climate Transparency, 2020, as cited in OECD-IEA, 2020). High government subsidies to fossil fuel and fossil fuel-based electricity, especially for residential consumers, reduce the economic viability of energy efficiency and installation of on-site renewable energy (WRI, 2019).
- Residential electricity is not taxed. Indeed, residential electricity consumption is subsidised at 20% (Black et al., 2021)*, which reduces the economic case for both energy efficiency and the installation of on-site renewable electricity* (WRI, 2019).

Economic and Financial

- Energy renovation of buildings has been hindered by split incentives (Black et al., 2021).
- Energy efficiency market development in Mexico has been hampered by the lack of appropriate financing products for ESCOs (IADB, n.d.). The limited market capacity of the ESCOs inhibits the expansion of the existing building segment of the market (WRI, 2019, as cited in Sustainia, 2018).

Capacity

- Incorporating the IECC-Mexico building energy code into local legislation is the only way to make it mandatory (WRI, 2019). As most local jurisdictions have little capacity and experience with energy efficiency, only a few local governments are formally implementing the national building energy code in Mexico (Mackres & Loutfi, 2020; WRI, 2019).
- Most private developers and builders dominating the construction industry still need knowledge of technology and economical solutions (PEEB, 2019), which is a significant barrier to implementing zero-energy buildings.

Information

The low awareness of energy efficiency among owners and investors combined with the limited ESCO market capacity hinders energy retrofits of non-residential buildings (Sustainia 2018).

6.10.2 Policy instruments for decarbonising Mexico's building sector

Table 10 presents an overview of policy instruments in the Mexico for decarbonising its building sector.

Table 10 An overview of policy instruments for decarbonising Mexico's building sector

Policy instruments		Description
Governance & planning instruments	Policy roadmaps for building decarbonisation	A Roadmap for Building Energy Codes and Standards was released by the Ministry of Energy (SENER) and the National Commission for the Efficient Use of Energy (CONUEE) in 2017 (Black et al., 2021). It intends to reduce energy consumption in buildings by 35% by implementing energy efficiency measures and by only constructing zero-energy buildings by 2050 (Black et al., 2021). Additionally, it anticipates that an energy building code will be enforced in all states by 2030 (Black et al., 2021). The goal of the guiding axes, established by the roadmap, is to develop a new system utilising low-carbon technologies, which are needed for planning and developing plans, policies, and programs and improving technical capabilities for project management (USMEX, 2021). There is also an emphasis on establishing mechanisms for institutions and programs and supporting research and development in energy efficiency and technologies (USMEX, 2021). The implementation of the Roadmap has not been monitored since 2017, as the technical committee for the Roadmap has not convened (Climate Transparency, 2021a). Mexico does not have a strategy for the renovation of existing buildings. In 2018, SENER published a geothermal roadmap for direct geothermal use in Mexico, which forecasts 3,800 MWt of production by 2030, out of which

		2,400 MWt will be separated brine installations in the geothermal fields expected to be operated by that year (Gutierrez-Negrin et al., 2021).
	Pricing mechanisms	In 2019, Mexico generated USD 307million in revenue from its national carbon tax introduced in 2014 (Climate Transparency, 2020). In 2021, Mexico's carbon taxes covered 58% of energy-related CO2 emissions (OECD, 2021a). Natural gas was excluded from the carbon tax imposed on fossil fuels, which reduced the effectiveness of carbon pricing in the building sector (OECD, 2021a). The three-year pilot phase of the Mexican Emissions Trading Scheme (ETS), covering the energy sector and large industrial installations, started operating on January 2020 (Graichen et al., 2021). The operational phase is planned to be commenced in 2023 (Climate Transparency, 2020).
	Energy Efficiency Obligations	No
	Energy efficiency funds	The government established trusts and funds to promote building energy efficiency (Copenhagen Centre & Building Efficiency Accelerator, 2019). The public policies on energy efficiency are supported by two primary mechanisms, namely the Fund for the Energy Transition and Sustainable Energy Usage (FOTEASE) and the Trust Fund for Electrical Energy Savings (FIDE) (IADB, n.d.). The FOTEASE, managed by Commission for Efficiency Energy Consumption and operated from 2008 to 2015, funded 41 projects to promote renewable energy use and sustainable technologies through reimbursable and non-reimbursable grants (AHK Mexico, 2022). The FIDE, formed in 1990, provides loans with favourable conditions to promote the implementation of energy efficiency measures in residential and commercial buildings and industrial and public facilities (AHK Mexico, 2022). In 2011, the Mexican government initiated the Sustainable Housing NAMA to provide financial assistance for constructing affordable and energy-efficient housing (Oates et al., 2021). Various financing packages have been made available to developers and homeowners to cover the upfront costs (UNFCCC, n.d.).
	Removing subsidies for fossil fuel	In 2019, USD 17.1 billion was spent on fossil fuel subsidies in Mexico (Climate Transparency, 2021, as cited in OECD-IEA, 2020). Petroleum received the most subsidies (USD 12.5 billion), followed by natural gas (USD 2.6 billion) and fossil-fuel-based electricity (USD 2 billion) (Climate Transparency, 2020), as cited in OECD-IEA, 2020). The existing electricity subsidies for residential consumers have been increased during the pandemic in 2020 (OECD & IEA, 2021). The high government subsidies to fossil fuel and fossil fuel-based electricity reduce the economic viability of energy efficiency and installation of on-site renewable energy (WRI, 2019).
	Phasing out fossil fuel boilers	No

	Presence of a dedicated political body	SENER is in charge of energy efficiency as a part of Mexico's energy strategy and policy regulated by the Energy Transition Law established in 2015 (USMEX, 2021). As a decentralised body of SENER, the functions of The National Energy Efficiency Commission (CONUEE) include promoting energy efficiency, enforcing energy standards and providing technical expertise and advice for the sustainable use of energy (USMEX, 2021).
Regulatory instruments	Building energy code	In 2014, Mexico introduced its building energy code, International Energy Conservation Code–Mexico (IECC-Mexico), based on the International Code Council methodology (IEA, 2019b). It covers residential, non-residential, as well as new and existing buildings. It is a voluntary code (IEA, 2019b). State and municipal adoption of and incorporation into local legislation make the national code mandatory (WRI, 2019). The Roadmap for Building Energy Codes and Standards released in 2017 anticipated that an energy building code would be enforced in all states by 2030 (ACEEE, 2022). Since 2018,44% of building energy consumption has been covered by the mandatory building codes (IEA, 2021). Moreover, the national retrofitting codes for commercial and residential renovations are in place in Mexico, and there are mandatory building envelope standards for new buildings and retrofits (ACEEE, 2022). However, it is necessary to impose more stringent measures to ensure compliance with the building envelope standards (Climate Transparency, 2020).
	Product-specific minimum energy performance standards (MEPS)	In Mexico, products are subject to NOMs (mandatory) and NMXs (voluntary) standards (IEA, 2019e). The first set of MEPs was adopted as energy standards in 1995 (IEA, 2019e). It has been mandatory to comply with these energy standards for equipment whose energy consumption accounts for up to 55% of its final energy consumption (USMEX, 2021). The energy requirements for equipment have gradually evolved and aligned with the standards applied in US and Canada (USMEX, 2021). At the end of 2020, 87 test laboratories, 215 inspection units, and 17 certification bodies were available in Mexico to assess conformity (USMEX, 2021).
Economic instruments	Financial incentives	Within the NAMA Facility program, e.g. subsidies were provided to developers to cover the extra cost associated with energy efficiency improvements and technical assistance for building 8000 homes with passive house standards (Oates et al., 2021). The Green Mortgage program, initiated in 2009, offers financing for acquiring approved eco-technologies, contributing to the reduction of water and energy consumption in residential buildings. (Oates et al., 2021). As part of the EcoCasa Programme, SFH offers concessional loans and technical assistance to low-income housing developers when they construct the building in a way that generates at least 20% less GHG emissions compared to conventional buildings (Oates et al., 2021).

		In Mexico City, the Sustainable Buildings Certification Program provides tax incentives for sustainable building retrofits in the form of reductions of property taxes and payroll taxes to encourage investments in green building technologies (C40 Cities, n.d.). Most financial incentives are used for retrofits and residential buildings, few financial incentives are available to stimulate interest in the new building and beyond residential buildings (Becqué et al., 2019).
Promoting business models& financing	Policies promoting energy services- ESCOs	The ESCO concept was first introduced in Mexico in the 1990s (The Global ESCO Network & Copenhagen Centre, 2020). 30 to 40 ESCOs operate in Mexico (KfW, 2021). Approximately half of these ESCOs are grouped in the AMENEER (Asociación Mexicana de Empresas de Eficiencia Energética) (KfW, 2021). Mexico has utilised the ESCO scheme for energy efficiency projects for over 20 years (APEC, 2017). Approximately 25 companies are organised in the Mexican Association of ESCO Companies (AMESCO), implementing projects in industries, hotels and local government buildings (APEC, 2017). In 2014, a shared savings energy performance contract was developed by a working group that includes CONUEE, AMESCO, the Mexican Social Security Institute (IMSS), Mexico's Tributary Administration Service (SAT), and GIZ (APEC, 2017).
	Policy promoting One-Stop-Shop	No
	Financing instruments	Nacional Financiera (NAFIN), one of the leading development banks in Mexico, released its Sustainability Bond Framework enabling it to offer green, social and sustainability bonds in areas including renewable energy and energy efficiency (GGGI, n.d.). The programme "Cambia tu viejo por uno nuevo" (Replace your old one for a new one), promoting the replacement of old inefficient electrical devices with new energy efficient ones, was launched by the SENER and implemented by the Trust for Saving Electricity and the National Developing Bank (RENONBILL, n.d.). The on-bill scheme, implemented by the project, enabled users to access financing to upgrade their equipment through their utility bills (RENONBILL, n.d.). The program of "Massive Eco-Business Credit" (Eco-Crédito Empresarial Masivo) for financing SMEs aims to support micro, small and medium-sized enterprises in replacing their old equipment with new energy efficient ones through CFE's electricity bill (AHK Mexico, 2022).
Information Instruments	Building rating and disclosure policies	Mexico does not require energy performance certification (Baker McKenzi, 2022). However, it is issued if a building meets the requirements specified in the NMX (Baker McKenzi, 2022). To enhance the involvement of local governments and municipalities, a labelling scheme for new buildings was introduced by CONUEE based on its strategy named "Energy

		Performance Rating System for Buildings of the Federal Public Administration" (Copenhagen Centre & Building Efficiency Accelerator, 2019). Many other voluntary programs are issuing certification for sustainable and green buildings in Mexico. The LEED certification for green buildings, the Certification Program for Sustainable Buildings, offering a range of tax incentives since 2008, the EDGE certification, which was initiated EDGE Zero carbon certification in 2019 are some examples of these programs (Baker McKenzi, 2022; USGBC, n.d.; WRI, 2019).
	Energy labelling schemes of products	As part of the MEPs process, a mandatory comparative energy labelling is applied for domestic appliances, including room and central air conditioners (APERC, 2015; SIST, n.d.). Labels for these products indicate their efficiency levels compared to MEPS (SIST, n.d). MEPs and test procedures for specifying equipment performance are considered in developing standards (SIST, n.d.). CONUEE regulates the energy label and ensures compliance (APERC, 2015; SIST, n.d.). Mexico also has a voluntary energy labelling programme named "Electric Power Saving Trust Fund (FIDE)", which certifies the products comply with the specified requirements (Copenhagen Centre & Building Efficiency Accelerator, 2019).
	Policies supporting targeted energy advice	No
RD&D policies	RD&D policies foster innovations	In 2018, the government established FSE to finance scientific research and technology development in energy efficiency (Copenhagen Centre & Building Efficiency Accelerator, 2019; SENER, 2016). In collaboration with the University of California, FSE started a 10 million dollar research initiative to improve building energy efficiency (Berkeley Lab Mexico Energy Initiative, n.d.).
Policies supporting capacity building	Training and education: Training programs for local governments on requirements and compliance Training and certificate programs for building inspectors Sponsored university degree programs on building energy efficiency	The following programs are examples of training activities conducted in the energy efficiency field: E4 program: The capacity of stakeholders on the implementation of building codes was improved through the online course developed by IEA in collaboration with CAF (IEA, 2021). Sisevive-EcoCasa's online portal: The capacity of small and medium-sized construction companies was improved through the training and communication events organised on Sisevive-EcoCasa's evaluation and labelling tool and certification of buildings (Oates et al., 2021). In addition, PROSENER 2020-2024 intends to integrate energy efficiency into professional and technical programs curricula and ensure that professionals continue to be trained by unions and business organisations (USMEX, 2021).
	Certification of qualified actors	NABCEP (North American Board of Certified Energy Practitioners) and SEI Solar Professionals Certificate Program (SPCP) certify installers and technicians in the solar industry (SEI, n.d.).

Lead by example		The law of the State of Sonora regarding the promotion of renewable energy and energy efficiency makes it possible for Energy Commission to carry out a procurement process for municipal and state buildings complying with the energy efficiency criteria (Copenhagen Centre & Building Efficiency Accelerator, 2019).

6.11 Vietnam

6.11.1 Major barriers and drivers to sectoral decarbonization in Vietnam

Structural

- After Vietnam has successfully implemented the universal electrification, the energy demand in the building sector has increased (APEC, 2022).
- Vietnam has experienced rapid economic growth and urbanisation in the past decade (PEEB et al., 2021). Besides, the building stock, amounted to 2,293 million m2 in 2018, is expected to grow further (PEEB, 2019b).
- The growth of middle class has created a strong demand for new affordable and social housing in Vietnam (PEEB, 2019b). As a result, the middle class, which is estimated to double by 2026 (Clasp, n.d.), is considered as a driver of growing energy demand.

Political

- A concessional tariff is applied to the electricity used in Vietnamese residential and administrative buildings (PEEB, 2019b). Due to high subsidies, domestic coal prices are kept artificially low, which hinders the expansion of renewable energy (Fuentes & Chapman, 2021, as cited in Dorband and others, 2020).
- There is no roadmap for building decarbonisation.

Politics

- The national government does not have an established regional presence based on steering committees, which further complicates the inter-level coordination of public agencies (Copenhagen Centre & Building Efficiency Accelerator, 2018).
- There is limited coordination between public agencies and a lack of a centralized agency that monitors the performance of agencies in enacting policies, which leads to fragmented governance (Copenhagen Centre & Building Efficiency Accelerator, 2018).

Economic and financial

- The energy-efficient buildings are likely to cost around 10-30 percent more to construct. (VietnamPlus, 2022). The high upfront costs, including high initial cost of energy efficient equipment are considered as a major barrier to energy-efficient building construction (Copenhagen Centre et al., 2018; Nguyen et al., 2017).

- The split incentives between building developers and users are regard as one of the major barriers to green buildings (Nguyen et al., 2017).
- The market for ESCOs is still immature in Vietnam (ETP, 2022; OECD, 2021b). The inadequate regulatory framework is regard as one of the major barriers to ensure market confidence for energy performance contracting (OECD, 2021b).
- Lack of access to financing: Due to additional risks involved, many local banks are reluctant to lend to companies operating in renewable energy and energy efficiency sectors (ADBI, 2018). The limited existing energy efficiency lending is available to only a few large creditworthy companies (WB, 2019b). ESCOs are struggling to access finance due to the high collateral requirements of local commercial banks as well as their weak balance sheets (OECD, 2021b; WB, 2019b).

Capacity

- Due to the lack of resources and expertise for building inspections and commissioning examinations, it is hard for the VEEBC to have any real impact at the local level (Copenhagen Centre et al., 2018).
- Building energy efficiency is hampered by low awareness and technical capacity within the construction industry (Da Nang, 2018). ESCOs need extensive project-based capacity building in Vietnam to acquire the missing Investment Grade Audit (IGA) and Monitoring and Verification (M&V) skills through trainings and certification (ETP, 2022).

Information

Most people do not fully understand the benefits of economic and efficient energy use (ADB, n.d.; OECD, 2021b). Energy-saving criteria have not yet been considered when buying electrical appliances (OECD, 2021b).

6.11.2 Policy instruments for decarbonising Vietnam's building sector

Table 11 presents an overview of policy instruments in the Vietnam for decarbonising its building sector.

Table 11 An overview of policy instruments for decarbonising Vietnam's building sector

Policy instruments		Description
Governance & planning instruments	Policy roadmaps for building decarbonisation	In Vietnam National Housing Strategy 2011, building energy efficiency was mentioned, although specific goals still needed to be outlined (PEEB et al., 2021). In the National Green Growth Strategy, green building development and energy efficiency of buildings were specifically addressed (MNRE, 2019, as cited in Climate Action Tracker, 2022). The government has issued Vietnam National Energy Efficiency Program (VNEEP) 2019-2030 as an overall energy efficiency strategy, which only have the following two targets related to the building sector:

		• To certify 80 buildings as green buildings by 2025 and 150 buildings by 2030 (Ministry of Industry and Trade, 2018) • To assure an efficiency rate between 8 - 10% across all national commercial energy consumption for the period of 2019-2030, based on the energy demand forecasts in the National Power Development Plan from 2011 to 2020 with consideration to 2030 (Ministry of Industry and Trade, 2021) With the limited focus of building sector, we do not perceive VNEEP as a policy roadmap.
	Pricing mechanisms	On January 1, 2022, the amended Law on Environmental Protection legalised the establishment of a carbon pricing mechanism, which penalises emitters of GHG emissions based on the "polluter pays" principle (WB, 2021a).
	Energy Efficiency Obligations	No
	Energy efficiency funds	No
	Energy and urban planning	No
	Removing subsidies for fossil fuel	The electricity used in Vietnamese residential and administrative buildings is subject to a concessional tariff (PEEB, 2019b). The subsidy for coal consumption was USD 270 million in 2020 (Climate Transparency, 2020). High coal subsidies hinder the expansion of renewable energy in the country (Dorband et al., 2020, as cited in Fuentes & Chapman, 2021).
	Phasing out fossil fuel boilers	No
	Presence of a dedicated political body	Energy efficiency activities in the building sector are shared between the Ministry of Construction (MOC) and the Ministry of İndustry and Trade (MOIT).
Regulatory instruments	Building energy code	National Energy Efficiency Building Code QCVN 09:2013/ BXD (VEEBC) The Vietnam Energy Efficiency Building Code (VEEBC), which provides technical requirements for the energy efficiency of buildings, was published by the Ministry of Construction in 2013 (PEEB, 2019b). Compliance with the code is mandatory for all buildings with a total floor area over 2500 m2 (PEEB, 2019b). The Law on Economic and Efficient Use of Energy mainly focuses on buildings whose annual energy consumption exceeds 500 toes or 3 million kWh. It does not target all buildings subject to VEEBC (PEEB, 2019b). In 2017, QC 09/2013-BXD was revised to incorporate better ventilation, air conditioning, lighting, and water heating performance (Ministry of Industry and Trade, n.d.).

	Product-specific minimum energy performance standards (MEPS)	Number of appliances and equipment covered: 14 (THƯ VIỆN PHÁP LUẬT, 2019) In 2015, Vietnam revised standards for room ACs (Clasp, n.d.). The revised standards exceeded the 2020 Association of Southeast Asian Nations Target (Clasp, n.d.). In 2020, the General Directorate of Market Surveillance was established by MOIT to ensure that the standards are enforced and monitored (Clasp, n.d.).
Economic instruments	Financial incentives	There are no financial incentives to promote energy efficient buildings (PEEB et al., 2021). The lack of incentive mechanisms limits the energy efficiency market demand and scaling-up implementation (ETP, 2022).
Promoting business models& financing	Policies promoting energy services- ESCOs	Decision 280 on VNEEP 3 aims to legalise the ESCO model in Vietnam, and the GVN is now working to remove barriers that stand in the way of ESCO market development (ETP, 2022).
	Policy promoting One-Stop-Shop	No
	Financing instruments	No
Information Instruments	Building rating and disclosure policies	Vietnam has no mandatory building certifications (Copenhagen Centre & Building Efficiency Accelerator, 2018). However, several voluntary programs include LEED, LOTUS, EDGE and Green Mark (Copenhagen Centre & Building Efficiency Accelerator, 2018). LEED and LOTUS, developed by US Green Building Council and Vietnam Green Building Council, respectively, are the two green building certification programs widely used in Vietnam (VGCB, n.d.).
	Energy labelling schemes of products	With the official Primer Minister Decision (No.04/2017/QD-TTg), energy labelling and minimum energy standards became mandatory for home and industrial equipment in 2017 (MoIT, 2019, as cited in Climate Action Tracker, 2022).
	Policies supporting targeted energy advice	No
RD&D policies	RD&D policies foster innovations	The Ministry of Natural Resources and Environment has a crucial role in research and development in energy and environmental protection (Copenhagen Centre & Building Efficiency Accelerator, 2018). The Vietnamese government must adopt supportive policies targeting research and development to accelerate clean energy finance and investment (Copenhagen Centre & Building Efficiency Accelerator, 2018).

Policies supporting capacity building	Training and education: Training programs for local governments on requirements and compliance Training and certificate programs for building inspectors Sponsored university degree programs on building energy efficiency	Except for training on building design and tools provided by professional organisations and academic institutions, Vietnam does not offer any standardised continuous learning opportunities focusing on energy efficiency in buildings (USAID, n.d.). USAID's Vietnam Clean Energy Program, implemented from 2014 to 2017, provided training to around 3000 civil servants and practitioners and university lectures on energy efficient building design, green building design and certification and energy simulation software (USAID, n.d.). There is a need to research and develop a training and certification model towards lifelong learning to improve the quality of energy management and auditing (VietnamPlus, 2021).
	Certification of qualified actors	No
Lead by example		No

7 Comparative analysis of policy packages for building decarbonisation across 10 countries/regions

This chapter compares policy packages for building decarbonisation across the 10 countries/regions analysed in the previous chapter 5, by assessing **the current landscape of policy instruments and the policy intensity of selected policy instruments**. Such a comparative analysis provides a snapshot of countries' efforts on building decarbonisation and helps to identify key similarities and differences across these countries.

7.1 Methods

Current landscape of policy instruments

The combination of different policy instruments is essential for overcoming the different market failures and bottlenecks inherent to the transition towards net zero buildings. *Section 5.1* describes how the primary functions of different policy instruments address each barrier. The list of policy instruments was used to map the current policy package for building decarbonisation in the country, i.e., which policy instruments are ***currently in place***. This was a first measure of how comprehensively the country tackles the barriers to building decarbonisation. Section 7.3 presents and compares different policy instruments deployed in the investigated countries. Prior to that, key barriers of the ten countries/regions are summarised and compared (Section 7.2).

Policy intensity of policy instruments

While the policy instrument landscape provides an overview of which policy instruments for building decarbonisation currently exist, policy design features are claimed to be essential for explaining policy *effectiveness* (Schmidt & Sewerin, 2019).

Schaffrin et al. (2015)applied the concept of policy intensity, which is defined as the "objectives" and "settings" of a policy instrument and the "organisation and mobilisation of resources" for the policy instrument. A higher intensity results in higher policy effectiveness. To operationalise the policy intensity concept, Schaffrin et al. (2015) developed six categories of indicators: *objectives, scope, integration, budget, implementation, and monitoring.* These indicators served as the basis for assessing the policy intensity of selected instruments in this study.

Considering the popularity of the policy instruments and the data availability across all countries, we will focus on a limited number of instruments within the governance and planning, regulatory, economic, and information categories, namely, policy roadmap, building energy code, economic incentives, and building information disclosure. It should be noted that not all intensity indicators can be applied to each policy instrument.

Accordingly, the policy intensity of the selected policy instruments for building decarbonisation was assessed as follows (Table 12). Considering data availability, the indicators of integration and budget were not assessed, and the comparison of financial incentives was focused on its scope. A cross-country comparison was conducted for each selected policy instrument, as soon as it is in place in the country. The results of the policy intensity assessment are described in Section 7.4.

Table 12 Policy intensity assessment

Policy instrument		Intensity measures	Detailed coding questions
Governance and Planning	**Policy roadmap**	Objective	% of new energy savings per year compared to total building energy consumption, or by absolute energy consumption targets for future target years; or by the level of operational targets on energy efficiency in new build, renovation (rates, depth), and low-carbon heating and cooling ➔ Compared with 1.5-degree scenarios of, e.g., climateanalytics, climate transparency
		Scope	Which building/product/technology types and target groups (including low-income households) are addressed by the decarbonisation actions included in the roadmap?
		Implementation	Targets and action plan including timeline: near-, middle-, or long-term? Is there a dedicated ministry(ies)/governmental body held responsible if these objectives are not met?
		Monitoring	Is there a specific monitoring process for the policy instrument, and by whom?
Regulatory instruments	**Building energy codes**	Objectives	Are energy/carbon specifications to be met duly accounting for technology progress and thus tightened over time until net zero?
		Scope	• The presence of building energy code for a) residential buildings; b) commercial buildings; c) new buildings); d) existing buildings (conditional on, e.g., major renovation happening anyway, or cases of sale and heritage; or unconditional, to be met in a certain year) • The % coverage of the country/building stock (if data available) • Technical requirements (optional)
		Implementation	• Mandatory or voluntary • Is there sanctioning?

		Monitoring	Is there only an inspection of plans before granting the building permit or also an onsite inspection during construction? Is there software for compliance checking? Are there 3rd parties that assist with compliance checking? Is compliance with conditional requirements for existing buildings ensured, and how?
Economic instruments	**Financial incentives**	Scope	Types of incentive measures implemented; The coverage: a) different target groups, in particular, low-income households; b) new and existing buildings; c) residential and commercial/municipal buildings
Information instrument	**Building rating and disclosure; renovation passports**	Scope	Coverage of building types (new and existing, commercial and residential; all or only at certain conditions, e.g., when sold or rented)
		Implementation	Mandatory or voluntary
		Monitoring	Is there a specific monitoring process for the policy instrument, especially on compliance, and by whom?

7.2 Summary of national barriers for building decarbonisation

Prior to analysing what policies are in place and their intensity, this section summarises and compares the key barriers of the ten countries/regions presented in Chapter 5, which are largely addressed by policies (Table 13). The identified barriers correspond to the reviewed barriers at the global level (Chapter 4). Several barriers are similar across different countries, for example:

- Structure barriers: Rapid population growth and urbanisation have driven building energy consumption in all developing and emerging countries. In most of these countries, such trends have also been accompanied by increased living standards and, thus, ownership of appliances. In developed countries such as the EU and Japan, large and rising floor areas per capita have significantly contributed to building GHG emissions.
- Political barriers: Most countries have highly subsidised fossil fuel use. Turkey, Vietnam, Mexico, and China have also subsidised energy prices for end users. Indonesia has very low electricity tariff.
- Economic barriers: High capital demand for construction or renovation and limited access to financing appear to be common barriers across all countries.
- Capacity barriers: A lack of capacity in the planning and construction sector, including skilled workforces and among responsible authorities to enforce building policies, is widely acknowledged as a critical barrier in investigated countries (no data on the USA and Japan).
- Information barrier: In most countries (except for India, Japan, and USA), a limited understanding of energy efficiency measures is cited as a barrier to their uptake.

Other barriers are only significant in certain countries:

- Politics barriers: The share of the decision-making between the national and local levels and limited coordination between the two levels makes enforcement of national policies and stringency vary across different regions. This is the case in South Africa, the US and the EU. In India and Vietnam, a lack of coordination among responsible ministries hinders the implementation of building policies.
- Political barriers: Three countries have no policy roadmaps for building decarbonisation to provide the market signal.
- Economic barriers: In three countries/regions (the EU, Mexico, and South Africa), split incentives are identified as a critical barrier, probably due to low home ownership rate. In Turkey, Vietnam, and South Africa, ESCOs that could play an essential role in energy retrofit are still at an early stage as supportive policies are limited. Besides, in China (some regions), South Africa, and the EU (some MSs), operational costs for heat pumps can be high due to high electricity prices.

Table 13 Summary of the key barriers in the ten countries

	Turkey	**Vietnam**	**Mexico**	**South Africa**	**USA**	**India**	**China**	**EU**	**Indonesia**	**Japan**
Structure	Rapid economic and population growth Urbanisation	Rapid economic growth; urbanisation Increased energy access; Increased demand of appliance and housing	Rapid urbanisation; Increased appliance ownership	Increasing population and urbanisation; Economic stagnation, almost a quarter of the cities' population living in informal settlements	Population growth; Increasing demand for housing and commercial space; increased use of electronic devices	Rapid urbanisation, population growth and income increase	Rapid urbanisation; increasing living standards	increasing floor area per capita due to increasing size of dwellings and households	Rapid population growth and urbanisation Increasing ownership of appliances and living in larger houses Increasing energy access	Growth of households and building floor area

	Turkey	Vietnam	Mexico	South Africa	USA	India	China	EU	Indonesia	Japan
Political	No roadmap for net zero building; Subsidised energy prices	No roadmap for net zero building; highly subsidised electricity	High subsidies for fossil fuel and residential fossil fuel-based electricity	High fossil fuel subsidies	No roadmap for overall building decarbonisation High fossil-fuel subsidies	Roadmap only for cooling.	Low heating price in Northern China Natural gas for residential heating is subsidised	High fossil-fuel subsidies	No roadmap for net zero building; High fossil fuel subsidies; Very low electricity tariff	
Politics	No dedicated national energy efficiency agency; Unclear roles and responsibilities of authorities to enforce building energy code	Limited coordination between public agencies	Devolved policy responsibility to local jurisdictions (with limited capacity)	Dispute over the share of responsibilities between national and local levels	The interaction of federal, state, and local laws determines energy policy.	Lack of inter-ministerial coordination		The transposition of EU regulation varies across different MSs.		
Economic	The high upfront investment and	High upfront investment;	High upfront investment;	The high upfront investment and lack of	The high upfront cost of energy efficiency	Lack of financial incentives for	High upfront costs,	The high upfront investment and	High upfront costs and a lack of access	High upfront costs and a lack of access to affordable

	Turkey	Vietnam	Mexico	South Africa	USA	India	China	EU	Indonesia	Japan
	lack of access to financing A small ESCO market; ESCOs' limited access to financing limited public funding availability	Split incentives An immature ESCO market; ESCOs' limited access to financing	Split incentives; Small ESCOs market; difficult access to project financing	access to financing; Split incentives; An immature ESCO market High electricity price for electrification Local authorities' lack of funding	and electrification and access to finance, esp. for over-burdened and underserved communities	energy efficiency Lack of access to financing	lack of access to financing; The high operational cost of heat pumps in some regions;	lack of access to financing; Split incentives; Limited public funding	to affordable financing; Few financial incentives	financing by SMEs
Capacity	Insufficient capacity of the relevant public authorities to enforce building energy code; The capacity gap in the	The limited capacity of the governmental agency; low awareness and technical capacity within the	The limited capacity of municipal stakeholders to adopt the national code; The limited capacity of	A severe lack of capacity among local authorities; The capacity gap in the construction industry		local authorities 'lack of capacity the for implementation and enforcement	A lack of capacities for building professionals	A lack of skilled workforce, technical expertise, and capacities	A shortage of skilled workforce, limited capacity of construction professionals	

	Turkey	Vietnam	Mexico	South Africa	USA	India	China	EU	Indonesia	Japan
	construction industry	construction industry	professionals for implementing net zero energy buildings							
Information	Limited public awareness; Lack of information for the purchase decision	Limited understanding of the benefits of energy efficiency	The low awareness of energy efficiency among owners and investors of non-residential buildings	Homeowners' limited understanding of energy efficiency measures			Limited understanding of the benefits of energy efficiency	A lack of information and awareness from private, public, and professional owners or tenant	A lack of awareness among stakeholders	

7.3 Policy mapping

Policy instruments		Turkey	Vietnam	Mexico	South Africa	USA	India	China	EU	Indonesia	Japan
Governance & planning instruments	Policy roadmaps										
	Pricing mechanisms										
	Energy Efficiency Obligations										
	Energy efficiency funds										
	Removing subsidies for fossil fuel										
	Presence of a dedicated political body										
Regulatory instruments	Building energy code										
	Product-specific MEPs										
	Phasing out fossil fuel boilers										
Economic	Financial incentives										
Promoting business models& financing	Policies promoting energy services- ESCOs										
	Policy promoting One-Stop-Shop										
Information Instruments	Building rating and disclosure policies										
	Mandatory Energy labelling schemes of products										
	Policies supporting targeted energy advice										
RD&D policies	RD&D policies fostering innovations										
Policies supporting capacity building	Certification of qualified actors										
Lead by example											

Figure 5 Mapping of policy instruments of the ten countries

As shown in Figure 5, except for Vietnam and Indonesia, where limited building energy policies have been implemented, in most countries, policymakers are highly aware of the importance of a policy mix for decarbonising the building sector, implementing instruments ranging from regulatory, economic, and information, to lead by example, and certification for qualified actors. The EU has the most comprehensive policy mix, followed by China and the US.

Overarching instruments, i.e., governance and planning instruments:

- Policy roadmaps have been formulated in five countries (India only focuses on cooling) (detailed comparison: 7.4.1).
- All countries except Turkey have dedicated national agencies responsible for building decarbonisation.
- Seven countries have introduced carbon pricing, but only the EU announced the introduction of explicit carbon pricing for heating in the building sector.
- Six countries have Energy Efficiency Funds to promote building decarbonisation. Mexico's government formed two domestic Funds in the 1990s and initiated the Sustainable Housing NAMA to finance affordable and energy-efficient housing construction. In South Africa, the Fund has been launched in partnership with KfW. The EU MSs have a long history of Energy Efficiency Funds. Also, at the EU level, several Funds are in place, some of which are established under EU ETS. Like the EU, the US has implemented the Funds (e.g. ,California, Oregon, Connecticut, Massachusetts) since the 1990s (Odyssee-Mure, n.d.-a).
- Five countries have implemented energy efficiency obligations (EEOs). In the EU, USA, India (only energy-intensive industries and hotels), and South Africa, EEOs have been implemented to promote energy efficiency, including in buildings. However, due to financial constraints, EEOs have been placed on hold in South Africa. EEOs in China have primarily focused on large end users.
- Only three countries (the US, the EU, and Japan) have committed to phasing out fossil fuel subsidies. However, in the US, legislative actions are still needed to phase out the subsidies.

Regulatory instruments have been widely implemented. All countries have building energy codes (detailed comparison: 7.4.2) and MEPS for appliances and equipment. The number of appliance categories with MEPS varies across the countries. The US and EU rank first with 42 appliances and equipment, followed by China, whereas India and Indonesia have less than appliances with MEPS.

Among the six countries with significant heating demand, two countries have explicitly banned (China) or planned to ban fossil fuel boilers (the EU with an agreed timeline). However, although the Chinese government has banned coal boilers in combination with subsidies, natural gas is still regarded as a clean fuel for heating in China. In Japan, the targets of ZEBs imply that fossil fuels must be phased out.

Eight countries have implemented ***economic instruments*** (subsidies, soft loans, taxes, or rebates) covering new and existing residential and non-residential buildings and energy efficient appliances & equipment (detailed comparison: 7.4.3).

Policies that promote two business models and financing:

- Eight countries have policies that support ESCOs, but the range of instruments used varies across the countries. A policy package has been implemented to promote ESCOs in the EU, China, and USA. In India, a super public ESCOs has implemented national-wide building energy efficiency programs. In other countries, only a few policy instruments have been implemented, e.g. legalising ESCOs (e.g., Indonesia and Vietnam). In South Africa, the country's ESCO market was mainly driven by ESKOM, which implemented its Standard Offer Programme (a kind of EEO) with ESCO projects between 2006 and 2013. ESCOs' activities slowed down in 2017 when ESKOM became reluctant to pursue additional energy efficiency programs (Zhu & Lütken, 2020).

- One-stop shops (OSS) have hardly promoted in the investigated countries. The EU has recently highlighted OSS as a promising instrument for energy renovation and specifies OSS in its Directives. As mentioned above, India has a public super ESCOs, which can be regarded as OSS. In China and the US, only pilots of OSSs were identified.

Information instruments:

- Most countries have implemented building information disclosure that can be used to assess energy efficiency in buildings, except Indonesia and Vietnam. (Detailed comparison: 7.4.4).
- All countries have energy labelling schemes for products. Except Japan, all these schemes are mandatory. The US scheme has continuous scales, which mark the highest and lowest energy use or efficiency and place the specific product in the spectrum. All other countries have categorical labels, giving a particular product ranking or scores according to energy use (Subramanian, Bastian, Hoffmeister, et al., 2022; VNEEP, 2021).
- Policies supporting targeted energy advice are only found in the EU and the USA. As of 2019, 18 EU MSs reported having targeted energy advisory services driven by EPBD and national policies. In the US, under a federal rebates program, a contractor first conducts an energy assessment of the home and designs a retrofit package accordingly.

RD&D policies

Half of these ten countries have RD&D policies fostering innovations. However, in most developing countries (except China and Mexico), there has been no or limited RD&D support from the government.

Policies supporting capacity building - Training and education: Certification of qualified actors

At the very least, most countries have programmes and guidelines for training and certifying personnel to check compliance with building codes, issue energy performance certificates, or carry out energy audits and recommend renovation measures. However, there are no such guidelines in Indonesia and limited opportunities in South Africa. In the EU, the EPBD requires professionals to be appropriately qualified, and those who carry out our EPC assessment and technical systems inspection are certified. Similarly, India, Japan and the USA have examinations to qualify as accredited energy auditors.

There is limited information on integrating training and certification into the curriculum, for example, in colleges and universities. However, universities in India and Germany include building energy performance certification or code compliance in the curricula of relevant undergraduate and graduate programmes. In China, building energy efficiency standards and technologies are required as part of the continuing education of registered town planners, registered architects, registered surveying and design engineers, registered supervision engineers, etc. In Mexico, PROSENER 2020-2024 aims to integrate energy efficiency into the curricula of professional and technical programmes.

Lead by example

Most countries have implemented government lead-by-example. In the EU, the US, South Africa, and China, lead-by-example has been included in the regulations (e.g., EED in the EU) or national strategies (14th Five Year Plan in China). In Mexico, such a regulation has only been found in one state. In India and Turkey, the instrument has been implemented on a project basis.

7.4 Policy intensity assessment

7.4.1 Policy roadmap

Five countries have national roadmaps for building decarbonisation, and India has a roadmap focusing on cooling rather than the overall building sector (Table 14).

Most of these roadmaps need to be more ambitious to lead to decarbonisation of the whole building sector. Mexico's building energy consumption should be reduced by 35% by 2025 to be PA-compatible (2050 is the timeline in the current roadmap) (Climate Transparency, 2020). South Africa's NEE aims at a 30% improvement in the average performance of residential buildings compared to 2015. In contrast, a recent analysis by the Climate Action Tracker suggests that the residential buildings' emissions intensity would need to decline by 50% to be compatible with the PA (Climate Action Tracker, 2021).China aims to peak building emissions by 2025. According to the IEA Announced Pledges Scenario (APS) scenario, direct emissions should have peaked by the mid-2010s in both the residential and services sectors, which would decrease by a quarter from 2020 to 2030. Japan aims to achieve ZEB levels for new buildings in 2030 but does not have an overall target for the whole building stock by 2030. In the EU, the proposal by the European Parliament in 2023, which is currently under trialogue negotiations, is the most ambitious in terms of its goal of zero-emission buildings for new construction and of at least tripling the current renovation rate by 2030. However, regarding MEPs for existing buildings, it needs to be clarified how EPC classes correspond to zero-energy buildings.

Regarding the scope, the EU, China, South Africa, and Japan roadmaps cover all building types, i.e., residential buildings and non-residential, new and existing buildings. Besides, most countries have concrete timelines for implementing roadmaps (No data is found for Vietnam). In most countries, monitoring of roadmap implementation has been absent or weak. For example, in South Africa, the government aimed to review the roadmap every five years but failed due to lacking capacity. In the EU, a review of the National Energy Efficiency Strategy of MSs shows that monitoring of the impact and progress remains weak due to, e.g., the lack of data and a clear approach (Economidou et al., 2022):

Table 14 Comparison of roadmaps in different countries

Indicators		Mexico	South Africa	India	China	EU	Japan
Objective	Are the targets PA-compatible? Are there targets for net zero buildings?	A Roadmap for Building Energy Codes and Standard: To reduce energy consumption in buildings by 35% and zero-energy buildings by 2050	South Africa's National Development Plan (issued in 2011) aims for zero emissions buildings by 2030。 The Post-2015 National Energy Efficiency Strategy (NEE) sets the 2030 target compared to the 2015 level	There is no roadmap for net zero buildings. India Cooling Action Plan: cross-sectoral; not specific about building envelop	Aims to peak CO2 emissions from its building sector by 2025	The EU aims to transform its building stock into zero-emission by 2050 with its revised Energy Performance of Buildings Directive (EPBD)	Japan aims to reach net-zero energy consumption for new buildings (ZEBs) and houses (ZEHs) by 2030 and all buildings by 2050
Scope	Which building/product/technology types?	New buildings	Residential and appliance, commercial, and public buildings; new and existing	Residential and non-residential building types are addressed. Technology interventions include fans, air coolers, packaged DX systems, VRF systems, Chillers and Room ACs	Residential buildings and non-residential; renewable integration; building envelop; electrification	Residential buildings and non-residential; new and existing	Residential buildings and non-residential; new and existing
Implementation	Targets and action plan including timeline: near-, middle-, or long-term?	A building energy building code to be enforced in all states by 2030	Concrete measures are mentioned	ICAP: concrete measures	2025 and 2030; complemented by 14th Five Year Plan	Clear timeline; MSs are required to achieve the adopted targets with their national strategies including timelines	ZEB for new buildings by 2030, but no action plan for the 2050 building stock target.

Monitoring	Is there a specific monitoring process for the policy instrument and by whom?	No	The government aims to review it every five years; due to a lack of capacity, many EE programmes are not reviewed on a timely basis	No	Annual reporting and monitoring	Weak	No information available

7.4.2 Building energy code

As shown in Table 15, Most countries have building energy codes for new buildings, including residential and non-residential buildings. In the EU, Vietnam and Mexico, the code also applies to existing buildings undergoing renovation. However, in Vietnam, it only applies to buildings with a total floor area of more than 2500 m^2 . In Mexico, the code only becomes mandatory after it is adopted locally.

In most countries, the code has been revised at least once since its inception to reflect technological advances and to tighten the code over time. China has updated the code more than four times since its introduction in 1986. In the US, the federal DOE works closely with two energy codes, ASHRAE and IECC, which have been continuously improved. Indonesia has updated its building code since it was first introduced in 2005.

In most countries, except the USA, Mexico and India, the code is mandatory at the national level. In the US, states are free to develop and mandate their own codes, usually based on ASHRAE and IECC. California has its own California Title 24 Building Energy Efficiency Standards. In Mexico and India, the code must be notified at the local or state level to become mandatory. In India, the code is still voluntary for residential buildings. In general, compliance with the code is low in most countries. High compliance is seen in China and the US, where the compliance process includes a site inspection. In the EU, compliance for new build can be considered medium to high, but compliance for existing buildings undergoing major renovation is generally low.

The level of monitoring building energy performance varies between countries. The EU maintains a Building Stock Observatory (BSO), a web tool that monitors the energy performance of buildings across Europe. In addition, Member States have their own monitoring tools and processes of varying quality. The US Energy Information Administration (EIA) conducts periodic Residential Energy Consumption Surveys (RECS) and Commercial Building Energy Consumption Surveys (CBECS), which analyse the fuels, end uses, appliances, space heating and cooling, structural and geographic characteristics, and other characteristics associated with building energy use. Mexico has statistics for commercial and public buildings, and South Africa has energy performance statistics for residential buildings only. China has statistics for residential energy use and maintains a data platform for large commercial and public buildings. In Japan, a consortium of industry, government and universities has developed a database for the energy consumption of commercial buildings (DECC). In Turkey, a building energy consumption monitoring database is under development. In India (apart from academic research initiatives), Indonesia and Vietnam, there is limited data on building stock and energy consumption at the national level, which hampers the development of concrete roadmaps and other policy areas.

Table 15 Comparison of building energy codes among the countries

Indicators		Turkey	Vietnam	Mexico	South Africa	USA	India	China	EU	Indonesia	Japan
Objectives	Accounting for technology progress and thus be tightened over time until net zero	issued in 2000 and was amended in 2008 and 2013	issued in 2013 and updated in 2017	will be upgraded from 2015 to 2050	update under review since 2018	DOE works closely with two popular energy codes,ASHRAE and IEEC, which have continously been improved	launched in 2007 and revised in 2017; The Energy conservation and sustainable building codes (ECSBC) being developed is regarded to be PA-compatible	launched in 1986,updated in 2001,2010, 2018	introduced in 2002, updated in 2010, 2018, and 2023.	issued in 2005, not updated	issued in 2015, updated recently
Scope	The presence of building energy code for a) residential buildings; b) commercial buildings; c) new buildings; d) existing buildings	a),b), c)	a),b), c),d) with a total floor area of 2500 m2 upward.	a),b), c),d)	a),b), c)	a),b), c)	a),b), c)	a),b), c) ONLY in urban areas	a),b), c),d)	a),b), c)	a),b), c)
Implement ation	Mandatory or voluntary	Mandatory	Mandatory	Voluntatry,becom ing mandatory if adopted at the local level	Mandatory	Not mandatory at the national level, Various states form their own codes	Mandatory for non-residential buildings (in the states where the code is notified); voluntary for residential buildings	Mandatory	Mandatory	Mandatory	Mandatory
	Compliance; Inspection	Low compliance	Limited inspection, low compliance	Varies across the states	Low compliance	Review plans Compliance check during construction On-site inspections, varis Compliance check prior to occupancy	No sanction. the level of compliance in various states and cities	high compliance due to stringent inspection	high compliance for new buildings	Low compliance	Compliance check prior to occupancy; low compliance, but with the new Code, the compliance rate is expected to be increased
Monitoring: M&E of building energy performance		Database being built	No building stock and energy consumption data collected	Commercial and public: statics	Residential: Energy balance statistic; Commercial and public:no	EIA collects detailed end-use energy consumption data	Insufficient data for policymaking, e.g. no end use, building floor areas, etc.	Residential: statistics; data platform for large commercial and public buildings	EU Building Stock Observatory:eurostat	limited data	DECC for commercial buildings

7.4.3 Economic instruments

Eight countries have implemented at least some of the economic instruments (Table 16)

Table 16 Comparison of economic instruments implemented in eight countries

Countries	**Types of incentive measures 1**) subsidies 2) soft loan; 3) tax incentives ;4) re-bates **Types of buildings** a) new b) existing buildings; c) residential d)commercial and public buildings; e) low-income households; f) energy efficient appliance & equipment
Turkey	2)-b,c 3)-d,f
Mexico	1)-a,c,e 2)-c,e 3)-b,c,d,f*
South Africa	3)-b,d,f
USA	1)-b,c,d,e 2)-c 3)-a,b,c,d 4)-c,e,f
India	1)-a (green buildings),c,d,e,f
China	1)-a (green buildings), b,c,d,e,f 2)-b,d
EU	1)-b,c,e,f 2)-a,b,c,d,e 3)-a,b,c,d,f
Japan	1)-a,b,c,d 2)-b,c,d 3)b,d,f

The US has the most diverse economic instruments, ranging from subsidies, rebates for appliances and equipment, soft loans, to tax incentives. It is followed by the EU (instruments used in MSs) and Japan, where grants, soft loans, and tax incentives have been deployed. India and South Africa have mainly deployed one economic instrument to a limited extent (India's subsidies are linked to green building rather than highly energy efficient buildings; South Africa's tax incentives only target large end users). Subsidies/grants (6), soft loans (5), and tax incentives (6) have been used in most countries.

In China, the EU, and USA, subsidies/grants are prevalent. In the US, subsidies are mainly provided to low-income households and public buildings. Rebates for appliances and equipment have also been offered to moderate-income households, covering up to 50% of the installation cost. In the EU, 61% of economic instruments supporting building energy renovations are grants. In China, subsidies are the primary instrument for energy retrofits and clean heating in residential buildings and energy retrofits of public and commercial buildings, high-star green buildings, and energy efficient and smart appliances.

Tax incentives have been used intensively in the USA, covering all building types, mostly energy retrofits and appliances/equipment; in the EU, as of 2019, eight MSs had implemented tax incentives (10% of all economic instruments). In most other countries with tax incentives, commercial buildings are the

target group. In other countries, tax incentives have been implemented to a limited extent, e.g., only targeting large users (e.g., South Africa), short implementation time (Turkey), or only at the local level (e.g., Mexico City).

Soft loans have been used in over half of the EU MSs. In the EU, 19% of economic instruments are soft loans and other loan programs available in more than half of the EU countries. In Mexico, supported by international funding, soft loans have been implemented for renovating residential buildings for over ten years. In other countries, soft loans are still in the early phase, e.g., Japan only recently adopted soft loans for energy renovations in residential and non-residential buildings. In all these countries, the major target group of soft loans are residential buildings.

Five of the eight countries have implemented incentives to support low-income households. Subsidies are used in all these countries. Some EU MSs also provide zero-interest loans to these households.

7.4.4 Building information disclosure

Most countries have implemented building information disclosure that can be used to assess energy efficiency in buildings, except Indonesia and Vietnam. At least one of the two types of instruments exists in each country. First are energy performance certificates (EPC), which show the building's energy consumption (measured or calculated) and compare its performance with a reference building. Examples are 'star rating for commercial buildings' in India, 'Labeling System for Energy Efficiency' in Japan, 'Energy Performance Rating System for Buildings of the Federal Public Administration' in Mexico, 'Home Energy Score' in the USA and instruments similar to EPCs in other countries, and of course the EU's EPC schemes. Second, endorsement labels, which only specify whether the building has met specified criteria, for example, Shunya (Zero) Labelling Programme for Net Zero and Net Positive Energy Buildings in India and ENERGY STAR Certification for commercial buildings in the US. However, except in China (in some regions), South Africa, Turkey and the EU, the building rating and disclosure policies are not mandatory. Moreover, in the countries where these are mandatory, these schemes apply only to certain categories of buildings, such as certain types of commercial buildings, residential buildings, and public buildings and based on the floor area of the building. Mostly, these schemes are available and applicable to new and existing buildings (Table 17).

Table 17 Building information disclosure in different countries

Countries	Scope	Implementation
India	New and existing; Commercial buildings	Voluntary
Japan	New and existing buildings; Residential and non-residential buildings	Voluntary
Mexico	New buildings; Public buildings	Voluntary
China	New and existing buildings; Commercial, public, and residential	Mandatory in some regions (for public and large commercial buildings)

Turkey	New and existing buildings; Residential and non-residential buildings	Mandatory
South Africa	New and existing buildings; Commercial and non-residential buildings (e.g., schools, shopping malls, theatres) greater than 2000 sqm; Government buildings larger than 1000 sqm.	Mandatory
USA	Existing buildings; Residential and commercial buildings	Voluntary
EU	New and existing buildings; Residential and commercial buildings	Mandatory

Besides the energy regulatory requirements, green building certification systems, which indicate energy performance and other resource use, can be found in most countries. For example, GRIHA in India, LEED in the USA, CASBEE in Japan, and Sustainable Buildings Certification Programme (PCES) in Mexico are voluntary. Besides, in China, green building certification is primarily voluntary. Still, in some regions, local governments require specific building types (e.g., large-scale public and commercial buildings) to be constructed as green buildings. In Indonesia, green building certification has been implemented in large cities, for instance, in Jakarta, it is mandatory for all large-scale new buildings. Furthermore, international green building certification systems such as LEED and EDGE are adopted in most countries.

8 Conclusion

Buildings are crucial in climate mitigation due to their significant share in final energy consumption and GHG emissions. However, the sector decarbonisation has been slow to move. In this report, we first synthesised existing literature on key barriers for three building mitigation strategies (improving building envelope performance, the shift from fossil-fuel-based and low-efficient to low carbon heating, cooling, and cooking, and energy efficient appliances and lighting), including structure, political, economic and financial, information, technical, and social and cultural barriers. We then reviewed how a broad range of policy instruments address the depicted barriers globally, including governance and planning, regulatory instruments, economic instruments, market-based instruments, information instruments, policies that support capacity building, promoting research and development, demonstration projects (RD&D), leading by examples, and policies promoting business models and financing.

As the second step, we analysed the same categories of key barriers in ten selected countries. The identified barriers at the country level largely correspond to the reviewed global ones. Several barriers are similar across different countries, such as rapid population growth and urbanisation in developing and emerging countries, highly subsidised fossil fuel use, high capital demand for construction or renovation and limited access to financing, a lack of capacity, and a limited understanding of energy efficiency measures. Other barriers are only significant in certain countries, such as little coordination between the administrative levels and responsible ministries, lack of policy roadmaps, immature development of ESCOs, high operational costs for electrification, and split incentives due to low homeownership rates.

As discussed in Section 7.3, most governments have applied a policy mix to address these barriers (except structural barriers). Vietnam and Indonesia have implemented limited numbers of policy instruments, which their climate and economic development may partly explain. Indonesia is almost entirely tropical, and Vietnam has both a tropical and a temperate climate. The “lucky” climate leads to little heating demand. Combined with historically low ownership of air conditioners (ACs), building energy efficiency measures have not been prioritised. It may change due to the increasing living standards and ownership of ACs and associated energy consumption, GHG emissions, governments’ enhanced awareness and energy saving targets, and power shortage (in Vietnam). The EU has the most comprehensive policy mix, followed by China and the US. These three countries have a long history of developing building energy efficiency policies. The EU and the US have started implementing building energy efficiency measures in response to the 1973 oil embargo (Alliance to Save Enegry, 2013; Economidou et al., 2020). China developed the building energy code for residential buildings in the cold climate zone in the 1980s and has amended the code and developed codes for other climate zones since then.

Regarding policy instruments in place, regulatory instruments are the most popular. All countries have building energy codes and MEPS for appliances and equipment. However, for building energy codes, except for China, the US, and the EU, the compliance rate is low in most countries. Besides, although all countries have MEPS, the numbers of appliances with MEPS vary significantly across the countries. MEPS cover about 40 appliances in the EU, China, and the US, 15-24 in South Africa, Turkey, Mexico, and Japan, and less than 15 in Vietnam, India, and Indonesia. Three countries (the EU, China, and Japan) out of six countries with significant heating demand have policies to ban fossil fuel boilers in buildings. Although there are no national policies in the USA, some US states made legislation allowing local governments to implement bans. Except for regulations, information instruments such as appli-

ance labelling, which is often implemented with MEPS, are found in all countries, showing similar variations as the MEPS. Another common instrument is building information disclosure, except in Vietnam and Indonesia. However, in most countries, building rating and disclosure are not mandatory. Most countries have implemented at least some economic instruments, among which subsidies/grants are most common. Tax incentives have been used widely in the USA to encourage uptake of building energy efficiency measures, possibly due to its long-standing tradition of using this instrument to stimulate economic growth, market-oriented approach to incentivise investment, and flexibility of policy design at the federal and state levels. Its successful implementation also depends on the effectiveness of tax collection system(Bertoldi, Economidou, et al., 2021). Furthermore, most countries have implemented government lead-by-example through regulations, national strategies, or projects.

While the above-mentioned regulatory, information, economic, and lead-by-example instruments have been widely implemented, several policy instruments have only been applied in a few countries:

- Policy roadmaps for building decarbonisation have only been implemented in half of the countries, and targets of most countries are not sufficiently ambitious to achieve PA.
- Only three countries (the US, the EU, and Japan) have committed to phasing out fossil fuel subsidies, which can be traced back to the G7 commitment in 2016.
- Only in four countries (the EU, USA, India (only hotel building), and South Africa) energy efficiency obligations (EEOs) have been implemented to promote building energy efficiency. In China, although EEOs have long been introduced, the instrument has mainly targeted large end users.
- Although most countries have policies that support ESCOs, in half of these countries, only a few policy instruments have been implemented, which leads to a slow ESCO market development.
- One-stop shops (OSS) have only been promoted in two countries (the EU and India).
- Policies supporting targeted energy advice only exist in the EU and the USA.
- RD&D policies fostering innovations have been implemented to a limited extent, particularly in developing countries (except China and Mexico) with no or limited RD&D support.
- Only the EU announced the introduction of explicit carbon pricing for heating in the building sector.

To summarise, PA-aligned building decarbonisation requires a comprehensive and effective policy package. Most country governments have recognised the importance of policy packages. Regulatory, information, and economic instruments have been widely implemented to different extents across the studied countries. To enhance their effectiveness, among others:

- Compliance with building energy codes should be strengthened, for which China, the USA, and the EU can provide good practice; The scope of the codes can be expanded to existing buildings, such as the EU case, in particular, in countries with less new construction(Pathak, et al., 2022).
- The scope of appliances with MEPs and labelling should be expanded in most countries, considering the increasing living standards and appliance ownership in developing countries.
- Building energy performance disclosure should be made mandatory, as it is proven powerful, especially for non-residential buildings (Pathak et al., 2022).
- Diverse economic instruments other than the prevalent subsidies/grants and innovative financing should be explored because subsidies can be unstable due to the limited availability

of public funding and are unlikely a significant driver for large-scale investments (Bertoldi, Economidou, et al., 2021).

Besides, we also found that several policy instruments have not been implemented in investigated countries, which could impede decarbonisation. Thus, it is recommended to:

- Develop policy roadmaps with PA-aligned targets and clear timelines, which provide a reliable planning framework for all market actors and reduce the risk for investors;
- Phase out fossil fuel subsidies, which create structural barriers to decarbonising energy efficiency. This can possibly be influenced through global governance;
- Apply EEOs for building decarbonisation which is proven to be cost-effective and places no burden on the national budget. The EU MSs and the US have extensive experience in implementing this instrument.
- Develop a comprehensive policy package to promote ESCOs development, which could address upfront financing and technological barriers for building decarbonisation. The EU, China, and USA can provide good practice here.
- Explore innovative mechanisms such as OSSs, which, e.g., aggregate small-size building projects and support stakeholders to access finance. The EU included the instrument in its major energy regulations
- Support targeted advice (e.g., subsidised), which could help the building owners to identify concrete energy saving opportunities and potentially trigger high and cost-effective investment in building decarbonization. Most EU MSs have targeted energy advisory services for energy renovation.
- Increasing funding for RD&D, which enables innovative technologies, services, and business models to be ready for commercialisation.
- Explore carbon pricing for fossil fuel use in the building sector which will be implemented in the EU by 2027. It could generate revenues for financing building decarbonisation investment, particularly for low-income households living in worst-performing buildings if explicitly linked to supporting programs and policies.

Overall, this study has shed light on the key barriers and policy instruments for building decarbonisation in ten countries. It identifies countries with comprehensive policy packages and which successfully implement specific policy instruments. However, the study has primarily relied on literature review. Additionally, the availability of data, particularly regarding the budget allocation for economic instruments, was limited. Moving forward, future studies could benefit from conducting more extensive empirical research to supplement the literature review. Furthermore, a valuable area for future research would be conducting an in-depth analysis of why certain policies are successfully implemented in one country but encounter challenges or fail to produce similar outcomes in others. Investigating the contextual factors can provide valuable insights into the transferability of good practice policies across different countries and regions.

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