

A Literature Review of Domestic and European Policy, Current Strategy and Opportunities Surrounding Building Decarbonisation

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Abstract

With the direct and indirect emissions from buildings often contributing significantly to the overall greenhouse gas emissions of countries across Europe, the decarbonisation of the buildings sector stands as a crucial step for countries towards meeting their wider climate goals. Significant challenges remain however hindering the efforts of Governments and organisations to implement effective decarbonisation measures. As such, this report aims to support Governments and organisations in identifying areas for improvement, concerning their building decarbonisation strategies, by outlining a series of best practises observed across Europe for facilitating building decarbonisation along with any key technologies driving decarbonisation efforts forward. To this end, building decarbonisation efforts across the UK, France, the Netherlands, Germany, Italy and Sweden have been summarised, presenting stated objectives, policies and measures alongside subsequent critique identifying areas of success and those in need of improvement. Regional case studies are also discussed for each respective country outlining instances in which local building decarbonisation efforts have shown particular initiative and present opportunities for the respective Government to improve upon its decarbonisation strategy. Such information has then been used to extract the desired series of best practises and key technologies tackling issues concerning six identified key areas surrounding building decarbonisation encompassing building renovations, building energy efficiency, decarbonising heating, skills and training, circular economy and public engagement. Key findings show ambitious financial incentives coupled with comprehensive private consultations have proved effective at stimulating building energy renovations with strict efficiency standards and appropriate enforcement ensuring such renovations are effective at increasing energy efficiency. Further development and deployment of smart meters, heat pumps and district heating are also widely accepted to be essential components of building decarbonisation with such technologies having seen previous success in facilitating decarbonisation. Developments in Hydrogen heating are also expected to show promising results in the future concerning the transition towards renewable heating. The implementation of such measures and technologies however will require strong initiatives to formulate a new 'green' workforce equipped with the necessary skills to do so. Such initiatives must also be supported by increased efforts towards improving environmental awareness amongst citizens and a transition towards circular building construction, consumption and recycling practises to enable buildings to become climate-neutral across their entire lifecycle.

Key words: *Building decarbonisation, European strategies, Policies, Measures, Technologies, Opportunities*

Executive Summary

Overview

With the need for increased decarbonisation efforts from Governments and organisations such to ensure wider net-zero pledges are achieved, the buildings sector stands as an important area in need of improvement with buildings often accounting for a large proportion of overall greenhouse gas emissions across European countries. Such efforts must seek to tackle both direct and indirect emissions as well as aiming to reduce the embodied carbon associated with both building construction and deconstruction. The transition away from natural gas in particular remains an increasingly urgent issue in a time of major price rises for natural gas in response to the outbreak of the 2022 Russo-Ukrainian war. Incentives for tackling such challenges are numerous and include:

- The creation of new jobs
- A reduction in household energy bills and operating costs across the economy.
- Improvements to health and the environment.

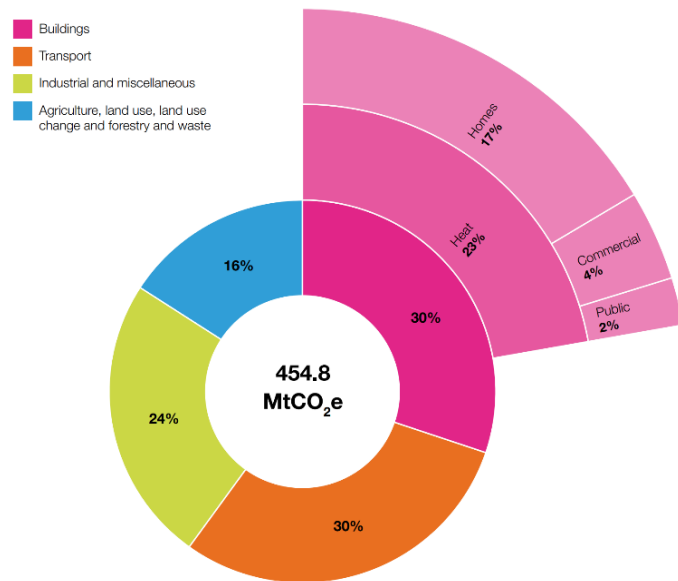


Figure i: Percentage breakdown of overall emissions from various different sectors within the UK in 2019.

Objectives

This report seeks to support Governments and organisations in identifying areas in which their current building decarbonisation strategies could be improved. To this end, the report seeks to:

- Provide a comprehensive summary of national strategies surrounding building decarbonisation for several developed European countries.
- Outline subsequent critique of discussed building decarbonisation strategies to outline areas of both success and those in need of improvement.
- Discuss regional case studies where such national strategies have been well implemented or improved upon at the local level.
- Derive from such information a series of best practises and key technologies for tackling issues relevant to several primary areas of building decarbonisation.





















Methodology

Information gathered is sourced primarily from government publications where building decarbonisation plans have been outlined with National Energy and Climate Plans (NECPs) and Long-Term Renovation Strategies (LTRS) referenced in many cases for EU countries. Critique has been sourced from dedicated institutions for each country where possible with reports from international organisations such as the IEA and the European Commission being used otherwise. At the regional level, climate strategy documents released by the relevant local authority have been used to source information regarding local building decarbonisation plans.

Once the stated objectives, policies, measures and critique of all countries had been summarised alongside the appropriate regional case studies, policies, measures and initiatives which could be confirmed to have seen success in achieving their intended aims were extracted. Instances where initiatives had been noted to show particular promise despite the absence of concrete results were also identified to highlight opportunities for success that could materialise in the coming years. Key technologies were then extracted and discussed based on their popularity amongst the discussed countries and the levels of success either seen or anticipated in facilitating building decarbonisation.

Key Findings

Table i: Extracted best practises from several developed European nations surrounding six key areas of building decarbonisation.

Area	Policy/Measure/Initiative	Country	Rating
Renovation of the existing building stock	Superbonus Scheme		
	Rekorderlig Renovering Method		
Improving building energy efficiency	Efficiency First Principle		
Decarbonising heating	District Heating Implementation		
	Hydrogen Exploration		
Circular economy	Anti-Waste and Circular Economy Law		
Skills and training	Green Jobs Taskforce		
Public engagement	Public Consultations		
	Rénov' Public Housing Renovation Service		
Rating Key			
	Policy/measure/initiative has seen tangible success towards achieving its intended goal.		Policy/measure/initiative shows originality and potential to be successful in the future.

In summary, for Governments and organisations looking to improve upon their decarbonisation efforts the following key findings are relevant:

- **Financial incentives** that ensure building energy renovations will yield immediate financial benefits coupled with **easy access to personalised consultations and advice** for property owners have been effective at stimulating increased energy renovations.
- Substantiated **guiding principles** concerning building energy efficiency have been successful at facilitating improvements to the requirements of **building efficiency standards**, the **enforcement** of such standards and **renovation legislation**, ensuring that when renovations are carried out they are effective at increasing the energy efficiency of the building.
- In addition to the roll-out of **smart meters**, it is widely recognised that the use and development of **heat pumps**, **district heating** and to a lesser extent **Hydrogen heating** will play a significant

role in building decarbonisation with the implementation of district heating having already enabled rapid decarbonisation in countries such as Sweden.

- Comprehensive initiatives concerning ***training and reskilling*** to produce a ***new workforce*** to implement building decarbonisation measures, such as the 'Green Jobs Taskforce' seen in the UK, will be needed to ensure that the skills are available to facilitate building decarbonisation whilst also ensuring that ***labour is effectively reallocated from fossil fuel industries*** and that those within such industries are able to benefit from the green transition.
- Wider efforts aimed at supporting a ***circular economy*** and ***increased environmental sobriety*** should not be neglected to ensure that buildings can become climate neutral across their entire lifecycle through ***improved construction practises/materials, occupants' behaviour and end of life recycling***.

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1. Introduction

2021 saw great leaps forward with regard to international climate negotiations and commitments with COP26 bringing nations ever closer to more fully decarbonising their economies and together limiting global warming to below the 1.5°C target set out in the Paris Agreement. However, despite the steady growth of global ambitions to decarbonise, current commitments often still fall far short of being able to reliably facilitate the great change that is required with such commitments still lacking the appropriate policy, funding and incentives to drive real world change forward. As such Governments and organisations must seek to expand and improve upon their efforts to decarbonise across all areas of their operations to ensure they can meet their own climate targets and mitigate the worsening effects of climate change.

One key area in which decarbonisation could be better facilitated is that of buildings. Of the total UK emissions recorded in 2019 (figure 1), 30% were contributed by buildings with heating being by far the largest contributor accounting for 23% of total UK emissions [1]. This places buildings together with transport as one of the two largest areas contributing towards CO₂ emissions in the UK followed closely by industry (24%) and agriculture (16%) [1]. Such a trend is not uncommon across Europe and highlights the importance that decarbonising buildings will have in ensuring that wider national net-zero climate targets are met. As such this report will provide an overview of the current state of building decarbonisation across developed nations before summarising and evaluating the recent approaches being taken by the UK, France, the Netherlands, Germany, Italy and Sweden towards it. It will then seek to extract and highlight a series of best practises and key technologies to subsequently help governments and organisations identify opportunities to reduce building related emissions more effectively going forward such to meet their climate targets.

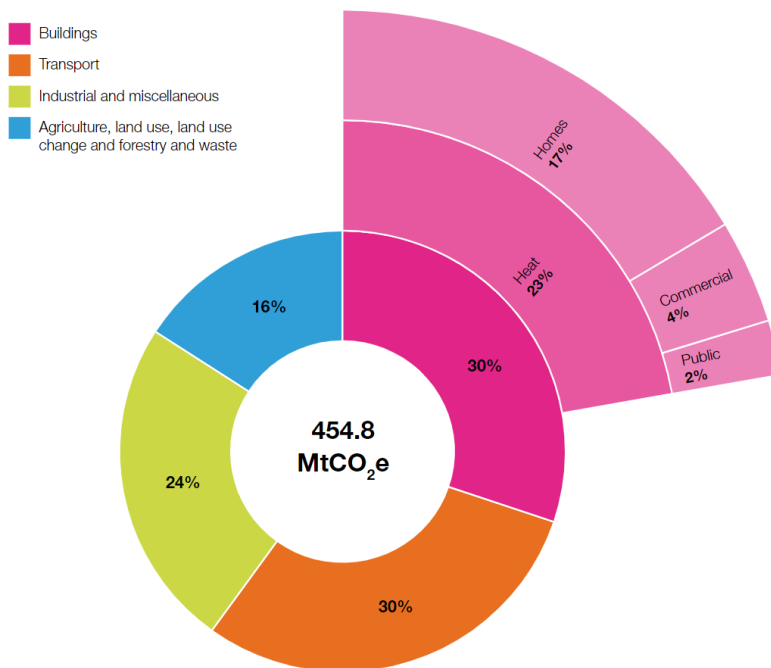


Figure 1: Proportions of total UK emissions in 2019 contributed by various sectors [1].

2. Building Decarbonisation

2.1. Building Emissions and Global Challenges

Buildings today contribute towards total carbon emissions in a variety of different ways whether it be via direct emissions through the combustion of fossil fuels for heating and hot water or via more indirect routes such as through the use of electricity for lighting and cooling. Furthermore, the process by which

buildings are commonly constructed often leads to further emissions in the form of the embodied carbon associated with construction, deconstruction, recycling and material production and transport.

With regard to indirect emissions, buildings often remain significant consumers of electricity where in the UK a reported three fifths of all electricity consumption was used to power buildings in 2019 [2]. As such reducing the electricity consumption and improving the energy efficiency of buildings will be a key focus going forward to tackle indirect emissions and better facilitate the phasing out of coal and the transition towards sustainable energy generation and usage.

However, it is the direct burning of fossil fuels (primarily for heating) that places the direct emissions from buildings as the most significant contributor towards overall building emissions [2]. As previously mentioned, heating accounts for a significant proportion of building related emissions with heating commonly facilitated through the burning of natural gas in gas boilers. In recent years many developed nations within the EU have grown increasingly dependent on imports of natural gas to keep its buildings heated (figure 2). This has left such nations subsequently vulnerable to geopolitical shocks, a reality now increasingly apparent and in need of attention and reform following the outbreak of the Russo-Ukrainian war pushing natural gas prices to record highs as international relations with Russia, a primary exporter, deteriorate.

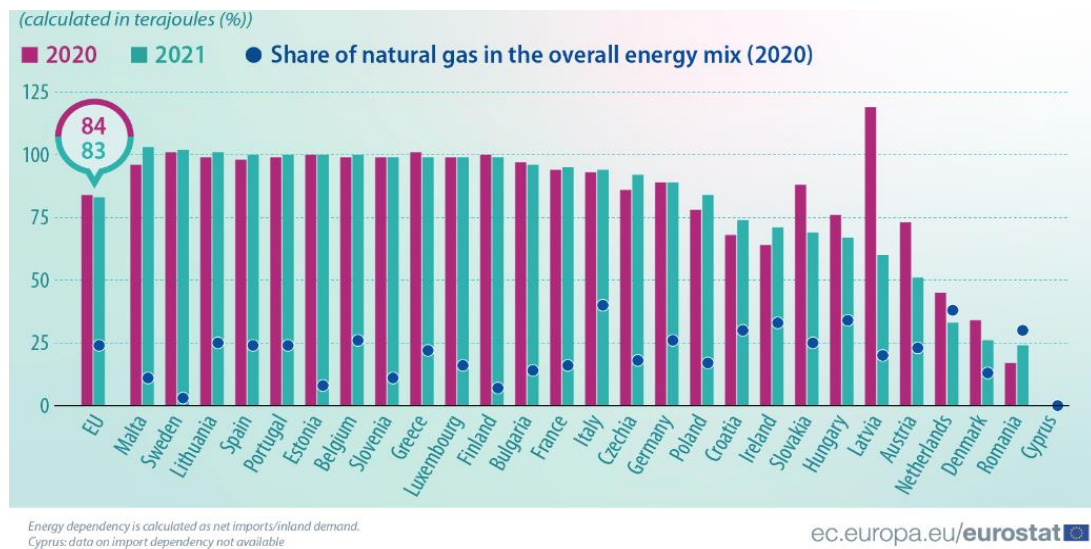


Figure 2: Natural gas import dependency of EU nations in 2020 and 2021 [3].

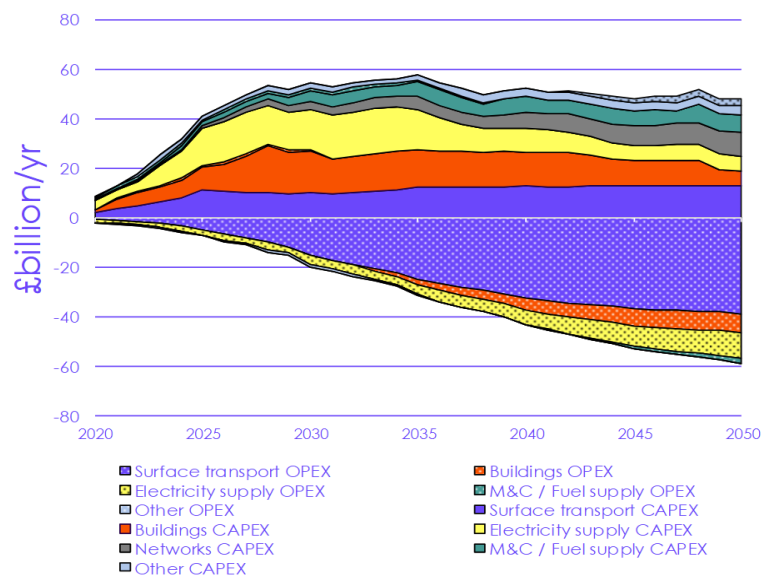
To this end, the development and widespread implementation of new domestic heating technologies alongside new insulation and energy storage techniques will play an increasingly important role in transitioning developed nations away from using fossil fuel sources such as natural gas to heat buildings towards more sustainable and robust methods of heating in the future.

Tackling such challenges will however require Governments and organisations globally to invest heavily in their futures whilst working together to both raise public awareness and take advantage of public sentiment to better deliver upon current promises and commitments. Such efforts now will enable the rapid decarbonisation of operations required to ensure businesses are able to adapt and thrive as the world transitions towards a more sustainable future.

2.2. Incentives to Decarbonise

Despite the great efforts Governments and organisations will need to go to to ensure the effective decarbonisation of buildings and the success of the wider green transition, many incentives exist enabling such efforts to prove both cost-effective and widely beneficial far into the future [4]. Such benefits include but by no means are limited to: i) job creation ii) reduction in household energy bills and iii) health and environmental benefits.

- i) It remains a significant challenge to implement the measures and technologies needed to decarbonise an economy, whether it be decarbonising buildings or the phasing out of coal in favour of new sustainable power generation techniques and doing so will require a considerable new low-carbon work force. Concerning building decarbonisation, roles will need to be filled in new business areas surrounding the retrofitting of old buildings with new heating/power technologies, the building of new green commercial and residential buildings, the construction of new utility delivery infrastructure as well as many more roles specifically related to individual business initiatives to decarbonise and other areas such as carbon capture and hydrogen. Such new roles together with support from Governments will help to reallocate labour where jobs surrounding fossil fuels have been lost which, if done effectively, will aid in keeping unemployment low throughout the green transition [4]. Keen adoption and support for a low-carbon workforce will also ensure organisations remain relevant in their services and appealing to customers and investors seeking opportunities in businesses set to grow as developed economies transition away from older unsustainable practises into new sustainable business areas.
- ii) Amongst other benefits, widespread investment in new green business areas has the potential to provide a unique opportunity to decarbonise residential and commercial buildings in a cost-effective manner, ensuring the lowering costs of renewable technologies are reflected in decreased consumer energy bills, supporting early adopters and the future rollout of new technologies. Additionally, ambitious and consistent investment over the coming decades has the potential to reduce operating costs across multiple sectors of developed economies. For instance, turning once more back to the UK as an example, it is stated that an average required investment of less than £10,000 per home over the next 30 years is projected to help reduce operating costs across the UK economy amounting to a total reduction in the order of hundreds of billions of pounds off current levels (figure 3) [4]. This demonstrates the great potential for growth across the global economy if Governments and organisations act now to bring the cost of renewables down and make the adoption of new sustainable technologies and practises more realistic and streamlined for consumers.



Source: CCC analysis.

Notes: Costs of electricity are included in the energy supply sector, whereas costs of other low-carbon fuels such as hydrogen and bioenergy are included in sectors that use these fuels. 'M&C' is manufacturing and construction. 'Other' category includes aviation, shipping, land-use, land-use change and forestry, agriculture, removals, waste and F-gases. CAPEX refers to additional annual capital investment. OPEX refers to savings due to operational cost reductions.

Figure 3: Capital investment and projected operating cost savings across the UK economy from 2020-2050 [4].

- iii) In addition to the wide array of economic benefits that decarbonising buildings will have, there also exists a plethora of advantages concerning human health and the environment. For example, the general health of a population stands to improve following the building of cleaner, better insulated homes with access to higher air quality. The British NHS currently spends approximately £1 billion annually across areas related to poor quality homes [4] and as such is in a position to recover this money for use across other areas following the decarbonisation and modernisation of our residential and commercial buildings. Furthermore, changing the ways in which we construct buildings and infrastructure to be more sustainable and less intrusive on the environment will help in supporting local wildlife and improving biodiversity ensuring as we continue to grow into the future, we are doing so symbiotically with the environment around us and not to its detriment. This will help to not only repair the damage already inflicted on the environment but also to mitigate the effects of climate change and the subsequent large expenditures that will be required if global warming continues to worsen.

As a result of such incentives, amongst numerous other benefits, countries across the globe in line with both the Paris Agreement and commitments made at COP26 are formulating and expanding upon their plans to achieve Net-Zero. To this end, countries are forming tailored approaches to tackle the unique challenges they face and take advantage of their own unique set of circumstances thus fostering great potential for innovation. In an attempt to explore such approaches towards building decarbonisation specifically, the following sections (sections 3-8) shall provide an overview of the current strategies being employed by several key European nations to decarbonise their buildings, summarising their stated objectives as well as the individual approaches being taken to transition buildings towards Net-Zero. Subsequent critique of proposed strategies shall also be outlined to highlight areas of both promise and those in need of improvement before examples of regional approaches are then discussed where particular initiative has provided opportunities for the relevant national and wider European strategies to be improved.

3. UK Government Strategy

3.1. Overview

The UK Government set out its plans to achieve net-zero in 2050, aiming to reduce emissions by at least 78% by 2035 before cutting emissions entirely by 2050 [1]. To this end the Government has identified the need to decarbonise the roughly 30 million buildings within the UK which as previously mentioned accounted for 30% of national emissions in 2019 (figure 1) [1]. Prior to 2019 the Government would release its 2017 ‘Clean Growth Strategy’ [5] followed closely by its 2018 ‘Clean Growth: Transforming Heating’ [6] outlining the options available to decarbonise Britain’s buildings. To fulfil the commitments made in these reports the Government would finally release its most recent and extensive proposals in the form of the UK’s ‘Heat and Buildings Strategy’ [1] and its ‘Industrial Decarbonisation Strategy’ [7] published in October and March of 2021 respectively. Such proposals build upon its 2020 ‘Ten-point plan’ [8] and outline its strategy to decarbonise Britain’s buildings by 2050.

3.2. Objectives

The following commitments and aims have been summarised from the UK’s 2021 ‘Heat and Buildings Strategy’ [1], representing the wider approach the UK is taking towards decarbonising its buildings. For plans aimed at decarbonising industrial buildings specifically, see the UK’s 2021 ‘Industrial Decarbonisation Strategy’ [7].

Table 1: UK Government commitments and target dates surrounding building energy renovations [1].

<i>Building Energy Renovations</i>	
<i>Commitment</i>	<i>Target Date</i>

Phasing out high-carbon fossil fuel heating systems in properties not connected to the gas grid.	2024 (non-domestic buildings) 2026 (domestic buildings)
Ensuring all new buildings in England are ready for Net Zero.	2025
Significantly reducing the energy consumption of commercial and industrial buildings by setting a minimum efficiency standard of EPC band B for privately rented commercial buildings and creating a new and innovative energy rating system for industry.	2030
Improving the performance of as many existing homes as possible to at least an EPC band C standard.	2035
Phasing out the installation of new natural gas boilers.	2035
Reducing the direct emissions from public sector buildings by 75% from 2017 levels by the end of the sixth carbon budget [4].	2037

Table 2: UK Government commitments and target dates surrounding its wider aims and objectives [1].

Wider aims	
Commitment	Target Date
Accelerating the growth of the low carbon heat network market through a series of complementary measures.	2025
Boosting financial support for social housing to reduce fuel poverty and boost low-carbon heat installation.	2025
Setting a long-term direction and clear signals for industry.	Ongoing to meet other target deadlines
Launching a new world class policy framework for energy related products.	Ongoing to meet other target deadlines
Considering how to ensure flexible demand and supply (including through smart technologies and energy storage) is taken into account across the full range of energy performance, fuel poverty and heat policies, including regulation and subsidy schemes.	Ongoing to meet other target deadlines
Developing a new low-carbon workforce pipeline with the necessary skills to meet the requirements of the Net-Zero building transition.	Ongoing to meet other target deadlines
Ensuring affordability by providing financial support for low-income households to meet capital costs.	Ongoing to meet other target deadlines

Table 3: UK Government commitments and target dates surrounding heat pumps [1].

Heat Pumps	
Commitment	Target Date
Setting a clear ambition for industry to reduce the costs of installing heat pumps by at least 25-50%.	2025
Growing UK-manufactured technology and capabilities, seeking a 30-fold increase in the manufacture of heat pumps.	2028
Facilitating the significant growth of the supply chain for heat pumps to a minimum market capacity of 600,000 new installations per year.	2028
Rebalancing energy prices to ensure that heat pumps are no more expensive to buy and run than gas boilers.	2030
Improving the appeal of heat pumps by continuing to invest in research and innovation.	Ongoing to meet other target deadlines

Ensuring the electricity system can accommodate increased electricity demand and heat pumps can be quickly and affordably connected to the network.	Ongoing to meet other target deadlines
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Table 4: UK Government commitments and target dates surrounding hydrogen and gas networks [1].

Hydrogen and Gas Networks	
Commitment	Target Date
Formulating policy to enable the blending of hydrogen into the current gas grid.	2023
Establishing large-scale trials of hydrogen heating.	2023 (neighbourhood trials) 2025 (village scale trials)
Expanding consultation on hydrogen-ready boilers enabling, or requiring, new natural gas boilers to be easily convertible to use hydrogen.	2026
Developing the evidence base necessary to take strategic decisions on the role of hydrogen for heating buildings.	2026
Increasing the proportion of biomethane in the gas grid (delivering 2.8 TWh of renewable heat per year).	2031
Developing hydrogen for heating buildings by comprehensively assessing the feasibility, safety, consumer experience and the other costs and benefits involved.	2050

3.3. Approach

To fulfil the objectives the UK government has set out within its 2021 ‘Heat and Buildings Strategy’ [1] (tables 1-4) it has quoted a set of five core principles, detailed below (table 5), to guide its actions throughout the 2020’s and beyond as it develops towards Net-Zero. It has also produced an indicative roadmap for when relevant measures and policies will be implemented between 2021 and 2028 (Appendix A) [1].

Table 5: Stated core principles and key steps and measures defining the UK Government’s approach towards building decarbonisation and delivering on its commitments [1].

<p><i>‘We need to take a whole-buildings and whole-system approach to minimise the costs of decarbonization.’</i></p>	<ul style="list-style-type: none"> • Hydrogen is identified as a promising low-carbon fuel alternative with the UK seeking to develop hydrogen production through both steam methane reformation and electrolysis to boost supplies to an equivalent 250-460 TWh by 2050. • Hydrogen gas storage is identified to be crucial in helping early development, smoothing out the intermittency of renewable energy and meeting seasonal demand variations for heat. • Pre-existing gas networks are being investigated to assess their suitability for using hydrogen gas in the future. • The UK Government’s Ten Point Plan [8] pledges support for the implementation of carbon capture, usage and storage (CCUS) across four industrial clusters by 2030 supported by an announced £1 billion CCUS infrastructure fund. • The UK’s ‘Hydrogen and Industrial Carbon Capture Business Model’ (ICC) will seek to support Government ambitions regarding hydrogen and CCUS whilst creating approximately 62,000 new jobs. • To facilitate the use of new heating technologies such as heat pumps and manufacturing processes such as electrolysis it is accepted that electricity demand will increase and that new sustainable methods of producing and storing electricity must be developed.
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	<ul style="list-style-type: none"> • The UK Government and regulators are working closely to implement smart systems to better match production with demand. • Uncertainty remains concerning how best to deploy hybrid systems. • Methods to build flexibility directly into the electricity network are being considered including intra-day storage i.e. lithium ion batteries, inter-seasonal storage i.e. power-to-gas-to-power systems, interconnection between UK energy systems and neighbouring countries, renewable generation i.e. burning biomass and back-up generation i.e. carbon capture.
<p><i>‘Innovation is essential to driving down costs, improving options and informing future decisions.’</i></p>	<ul style="list-style-type: none"> • Time and resources will be dedicated to drive research and innovation to improve the evidence bases informing decisions and develop new technologies and systems for wider scaleup and implementation. • Pledged Government funding in the form of ‘The Net-Zero Innovation Portfolio’ amounts to £1 billion as outlined in the Government’s ‘Ten Point Plan’ [8]. • The UK strategy encourages collaboration in research across industry, academia and third sector advisory groups both nationally and internationally to fulfil its aims. • Research an innovation is largely focused on: energy efficiency, heat networks, heat pumps, hydrogen, bioenergy, modifying the electricity system and improving consumer engagement with research in each area guided by clear goals.
<p><i>‘In parallel, we need to accelerate no- and low-regret action now.’</i></p>	<ul style="list-style-type: none"> • The UK strategy seeks to encourage business and industry by advocating no- low-regret action in which actions taken now will continue to be beneficial for stakeholders both now and in the future. • A proposed example is identified in the development and wider implementation of heat pumps as it is believed that across all predicted development paths towards the UK’s Net-Zero target the installation of heat pumps will be required with an identified minimum installation of 600,000 per year required to achieve Net-Zero in line with Government targets. • Additional identified areas of no- low-regret action surround transforming the market for heat networks (an area in the UK identified to possess one of the largest growth potentials in Europe with investment potential reaching between £60-£80 billion by 2050) and heat network zoning to support the development of new and existing heat networks of which there are currently 14,000 in the UK supplying heat and hot water to roughly 480,000 consumers. • £338 million will be invested over the next three years as part of a wider ‘Heat Network Transformation Programme’ to develop low-carbon heat networks and grow the heat network market.
<p><i>‘We will balance certainty and flexibility to provide both stability for investment and an enabling environment for different approaches to be taken to address different buildings.’</i></p>	<ul style="list-style-type: none"> • To provide flexibility for businesses in how they choose to prepare to decarbonise the UK is advocating the development of a low-carbon workforce. This will be achieved through both the retraining of the existing workforce (supported by a national retraining scheme and national skills fund) and the development of the next generation of skilled workers. • Required skills to transition the UK to Net-Zero are identified and categorised per technology type including the skills required for the implementation of energy efficiency measures, heat pumps, heat networks and hydrogen technologies.

	<ul style="list-style-type: none"> Plans for how the UK will meet this demand for new skills are outlined including the rollout of new industrial training programmes, apprenticeships and additional work courses. To deliver such plans the UK has launched an independent 'Green Jobs Taskforce' consisting of key industry bodies with the task of delivering 2 million Net-Zero jobs by 2030.
<p><i>'Government will target support to enable action for those in most need.'</i></p>	<ul style="list-style-type: none"> The UK Government is aware that comprehensive strategy is required for cost distribution, green finance, consumer protection, public engagement and monitoring and evaluation. Consumer engagement and confidence is noted as a key priority for the success of the UK's Net-Zero transition. Public engagement and education will seek to keep people informed and aware of how upcoming changes will affect them. Costs of the transition will be spread across public funding and private 'green' finance to ensure the Net-Zero transition is fair and that any burden is shouldered across multiple stakeholders. Direct financial support from the Government in the form of a boiler upgrade scheme, local authority delivery scheme, social housing decarbonisation fund and home upgrade grant seeks to ensure fair delivery of measures across the UK regardless of financial background. The supply of additional 'green' finance will be facilitated through innovation in green finance products such as mortgages, increasing the investment options available to households, building owners and businesses. Green mortgages offer more favourable terms to borrowers who are looking to move into a newly built energy efficient home or renovate an existing building subsequently incentivising such actions. Quality standards and a trained new low-carbon workforce will aim to protect consumers and ensure their expectations regarding new green technologies are met.

3.4. Critique and Recommendations

Following the release of the UK heat and buildings strategy the UK Climate Change Committee (CCC) has conducted an independent assessment of the Government's plans, summarised in a report released in March of 2022 [2]. Their overall assessment of the Government's strategy has been summarised below (table 6).

Table 6: CCC critique and recommendations concerning policy, delivery and next steps with regard to the UK's 2021 'Heat and Buildings Strategy' [2].

Critique	
Policy	<ul style="list-style-type: none"> Approximately one third of emission reductions required in 2035 are either not yet supported by a clear policy/plan, lack the required funding or lack any explanation as to how it will be delivered by the Government (figure 4). This critique is further supported by Zero Carbon Oxford who report that 96% of local authorities in the UK claim that funding remains a barrier to their climate action, and 93% that legislation also presents a barrier [9]. Insufficient enforcement mechanisms exist to ensure the energy efficiency of owner-occupied homes is improved. Instead, mortgage lenders have only voluntary targets to persuade borrowers. Inadequate levels of public funding have been provided to improve the fabric efficiency in social housing. The phasing out of gas boilers in commercial buildings lacks sufficient drive with an unreasonably late phase-out date of 2035.

	<ul style="list-style-type: none"> • The Government's plans do not break down the expected individual contributions of policies and technologies towards overall emission reduction. Furthermore, independent assessment by the CCC determines the overall reduction in emissions from the roll-out of low-carbon technologies to contribute approximately 18% less than required to meet the strategies targets (figure 4). This gap requires urgent clarification from the UK Government. • Current plans for retrofitting old homes do not factor in the need to adapt to a changing climate, failing to address the risks of overheating and flooding.
Delivery	<ul style="list-style-type: none"> • The remaining 65% of emission reductions are facilitated by plans exposed to at least some risk, with the majority exposed to significant delivery risk (figure 4). Such a reality reflects the Governments widely novel approach, the lack of detail it has provided with its plans and the need for more coordination with planning occurring at the local and devolved levels. • The Governments market-based approach for heat pumps has the potential to bring significant benefits surrounding innovation and cost however such a strategy will require continuous monitoring and appropriate support if development is to proceed as planned. Otherwise, the Government must be prepared to adapt its strategy to ensure its success. • Stronger Government support is needed to ensure the successful scaleup in training and reskilling. • Local authorities need to be sufficiently resourced to effectively conduct inspections and enforce EPC standards which themselves require improvement. • More needs to be done to better coordinate national strategy at the devolved and local levels including increased data sharing, improved local energy planning and heat network zoning. • Plans are not being enacted at sufficient pace with announced consultations yet to be initiated, concluded consultations not yet acted on and decisions due in 2022 still not announced.
Outlook	<ul style="list-style-type: none"> • Initial policies have been formulated for many areas including policies to drive the implementation of low-carbon technologies, energy efficiency measures and the strengthening of enabling policies surrounding measurement, enforcement and skills. • The strategy provides a clear direction for future action surrounding the decarbonisation of buildings. • Overall, many high-level intentions and ambitions for decarbonising heat and buildings are in place however significant detail is missing from current plans and policies, particularly for plans beyond 2025, concerning how necessary action to realise such ambitions will be facilitated and funded.
Recommendations and Next Steps	
<ol style="list-style-type: none"> 1. Ensure policy gaps regarding areas including, but not limited to, home energy efficiency and funding to decarbonise public sector buildings are filled. *** 2. Build and expand upon initial proposals for critical enablers such as skills, finance, information and governance. 3. Strengthen the coordination of Government strategy with the plans of devolved and local authorities. 4. Ensure major strategic decisions including those regarding the relative costs of electricity and gas for heating are made (For a summary of potential options identified by the RAP [10] see appendix B). *** 5. Increase the current pace to tackle the large number of planned consultations and policy papers to ensure the Government's ambitious proposals become firm policy in a timely manner and remain capable of delivering on Government commitments. 	

*** Working in line with these recommendations the UK Government continues to release new legislation and bill proposals, such as its new 'Energy Security Bill' published in July of 2022, outlining new major decisions, plugging existing policy gaps and providing more detail on how current plans will be supported.

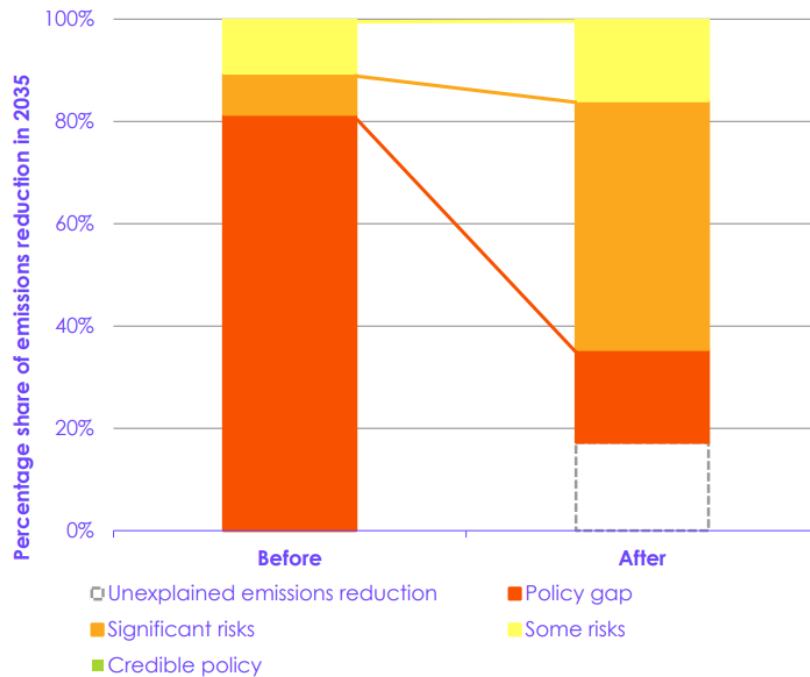


Figure 4: Percentage share of emissions reduction in 2035 enabled by policy of varying qualities before and after the publication of the UK's 2021 Heat and Buildings Strategy [2].

3.5. Regional Approaches

With such critique in mind, this section shall outline several regional approaches to facilitating the decarbonisation of buildings within the UK where particular initiative and ambition has been observed. Such approaches shall serve as examples to Governments and other organisations, including the UK Government, demonstrating where delivery and methodology surrounding building decarbonisation has the potential to be improved going forward.

3.5.1. Oxford

In Oxford, local universities, councils, hospitals, businesses and communities have come together to form 'Zero Carbon Oxford' or ZCO, a partnership with the goal of transitioning the city of Oxford to Net-Zero by 2040. This goal is already more ambitious than the 2050 target set by the UK Government and serves as testament to Oxford's commitment to leading the UK by example forward to achieving its Net-Zero targets. To this end, Oxford has released its 2040 Net-Zero Action Plan in 2021 [9] detailing exactly how Oxford intends to achieve its ambitious targets. The action plan contains many innovative approaches and ideas from which other local authorities as well as the UK Government could learn, namely the use of so called 'Sprint groups' to enact plans on the ground and the formulation of comprehensive roadmaps with the addition of multiple detailed pathways towards achieving Net-Zero.

- **Regional Plans** for Oxford with regard to building decarbonisation include supporting Government ambitions by allowing for up to 20% of the gas grid to consist of Hydrogen by 2023 (helping to facilitate the Government's suggested neighbourhood Hydrogen heating trials (table 4)) as well as aiming for 39% of homes to have new heat pumps installed by 2030 [9]. In addition to this, by 2030 Oxford intends to ensure 75% of new homes come equipped with rooftop solar technology and that 30% of existing homes have it installed [9]. Plans for 2030 also aim for all rented and fuel-poor homes to meet an EPC

C efficiency standard and that at least 19,600 existing homes will have been retrofitted with a minimum of one energy efficiency measure (such measures include cavity wall insulation, double glazing and solid wall insulation) [9]. Overall Oxford's current plans should bring domestic emissions down by a targeted 56% by 2030 [9] when local targets shall then be reviewed to reassess longer term plans.

- Sprint Groups** have been described as 'task-and-finish groups' created to achieve a specific objective with defined time and budget constraints. Such groups consist of specialists in the area of interest which will work cooperatively to explore and deliver potential solutions to an issue before the group is then disbanded [9]. Such an approach has several noted advantages, including providing the ZCO with flexible and agile action groups capable of being formed as required to achieve specific tasks thus providing the ZCO's drive for change with constant momentum. Furthermore, sprint groups ensure that those working on a given task are a tailored expert team of relevant individuals best suited to dealing with the groups assigned task, allowing for effective and efficient use of ZCO members and resources. Finally, the use of sprint groups allows for the significantly large workload involved in facilitating Oxford's transition to Net-Zero by 2040 to be spread across ZCO partners [9]. In summary sprint groups are the ZCO's answer to how to translate its ambitious plans into real world action and define a significant example for other UK authorities to follow and improve upon when seeking to transform plans into real world action.
- Detailed Development Pathways** have formed the backbone of ZCO's proposals to achieve Net-Zero by 2040 and set the standard for the level of detail required in such proposals to ensure the ambitions of the UK to achieve Net-Zero do not remain as ambitions beyond mid-century. For instance, for each action suggested by the ZCO (covering policies and regulation, research and development, capital investment, behaviour change, communication and education, governance and stakeholder collaboration, skills and supply chain and cross-cutting) details are included covering concepts, relevant pathway requirements, funding sources, implementation steps, owners, as well as action dependencies and risks. ZCO also go one step further by quantifying the overall impact that national dependency and policy deficit is having on the ZCO's plans to achieve Net Zero (figure 5) highlighting clearly what the UK Government must do to ensure plans and actions are successful and coordinated at the local level [9], an area previously described by the CCC as in need of improvement (table 6) [2].

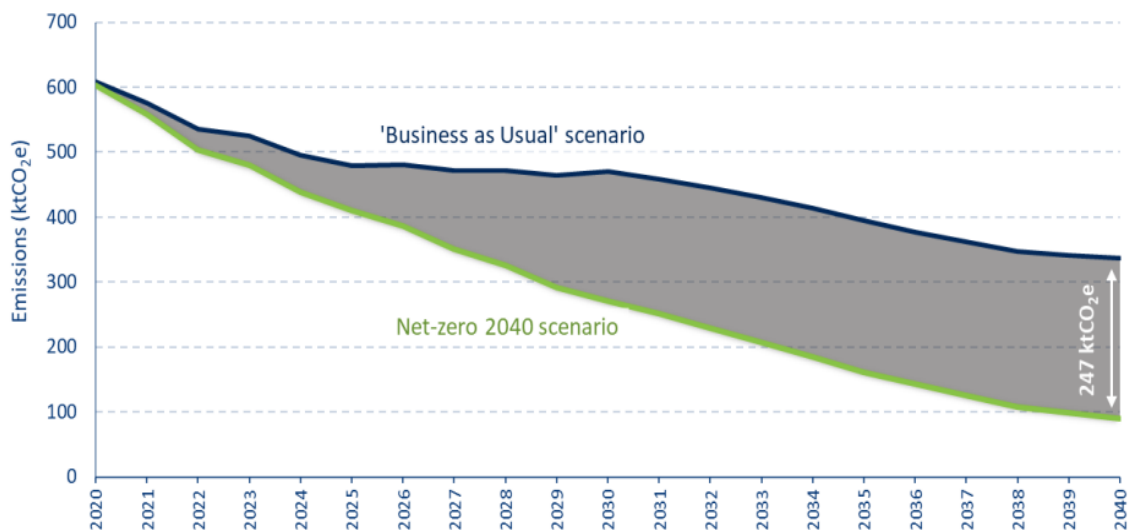


Figure 5: Emissions gap across 2020-2040 between the case following the successful implementation of ZCO plans (green) and what is currently possible given current legislation, initiatives and UK Government support (blue) [9].

3.5.2. London

Previously in 2018, the Mayor of London published the local authorities plans to decarbonise the city of London in the form of 'Zero carbon London: A 1.5°C compatible plan' [11], detailing the steps and current limitations of London's climate action. Since 2018 however, ambitions have expanded both nationally and locally to bring London's Net-Zero target date forward from 2050 to 2030 [12], a full 10 years earlier than Oxford's target cementing London as the spearhead of the UK's Net Zero climate ambitions. However, this leaves the city of London with less than a decade to fully decarbonise and achieve its significant goals. Consequently, London's approach towards decarbonisation has been particularly enthusiastic and innovative, utilising extensive modelling to simulate a multitude of development scenarios whilst fostering an informational approach to provide the London authority and UK Government with facts and options to inform future decisions.

- **Regional Plans** for Greater London surrounding building decarbonisation have already enabled new zero carbon homes in 2016 and the installation of smart meters across London helping to optimise energy management with further ambitions to insulate lofts and cavity walls throughout the 2020's to improve building energy efficiency [11]. Additionally, under current plans existing low efficiency boilers are to be replaced, paving the way for city wide deployment of heat pumps and other low carbon heating devices in the 2020's [11]. The London authority in recent years has also appealed to its population to help in decarbonising the cities buildings by advising that they obtain their EPC certificate to inform future home efficiency improvements, only use energy efficient appliances and switch energy supplier to a green tariff for electricity and gas [11]. Many of London's plans however, are noted to be especially reliant on increased Government support and timely national level decision making to be successful [11], a reality reminiscent of Oxford as well as many other local authorities and once again highlighted by the CCC (table 6) [2]. This subsequently ties the success of the regional Plans of London closely to the decisions and actions of the UK Government.
- **Broadening Ambitions** has challenged the city of London to lead one of the most significant decarbonisation efforts seen across developed nations, efforts that will require innovation and action superseding the plans of the UK Government. An analysis of the Net Zero 2030 target for Greater London published in 2022 [12] notes that waiting any longer to make major development decisions runs the increased risk of under-delivery and a more costly development process. As such the analysis recommends action must be taken within the next five years by the London authority to select its development pathway and start implementing the necessary actions and measures. Despite the remaining challenges, London's appetite for expanding upon its previous ambitions set an example not only for the UK Government but for other developed nations worldwide with London's actions over the coming decade having the potential to set the standard for how monumental change can be achieved through bold ambition, decisive action and innovation.
- **Scenario Modelling** has played a significant role in London's approach to decarbonisation, allowing for a wide array of decarbonisation metrics to be analysed in the case of multiple different development scenarios including no constraint pathways as well as pathways involving high electrification, high hydrogen and accelerated action (figure 6) [12]. Such analysis has allowed development pathways to be compared and contrasted as well as for the determination of which pathways remain compatible and preferable for achieving the wider decarbonisation aims of both London and the UK, narrowing down development

options and supporting local decision making. Furthermore, such an informational approach has also provided the London authority with the additional necessary details required to formulate comprehensive development plans and inform the major decisions needed to drive decarbonisation forward, subsequently highlighting the benefits of decarbonisation scenario modelling as an aid for decision making.

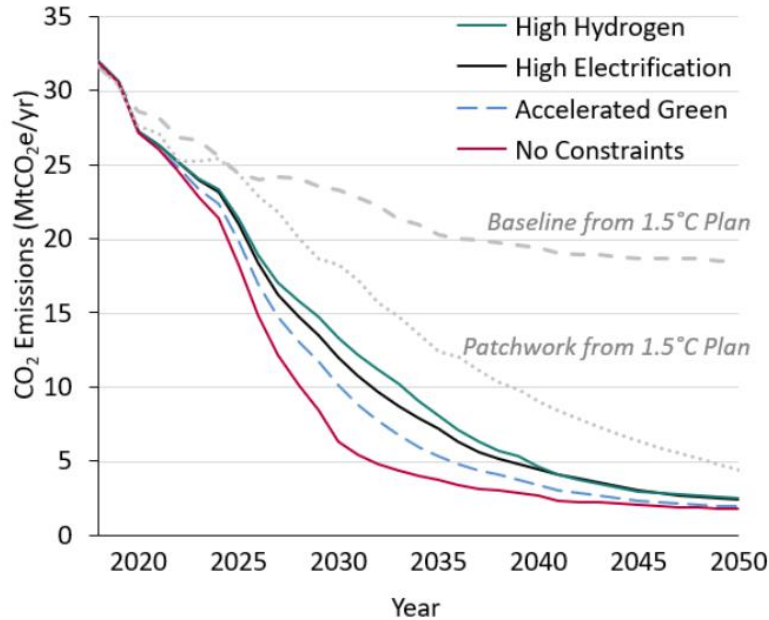


Figure 6: Annual emissions across Greater London between 2020-2050 for various development scenarios [12].

3.6. Summary



Table 7: Overall summary of the UK strategy to decarbonise its buildings.

UK Government Heat and Buildings Strategy	
Strengths	Weaknesses
<ul style="list-style-type: none"> The UK's plans are ambitious and far reaching in their scope, covering a wide array of areas and setting a clear direction for the country. The latest strategy lays a strong foundation for future improvements to be made. The UK's market-based approach towards heat pumps and heat networks stands to deliver many benefits including cost savings and increased levels of innovation. The UK are taking promising steps towards implementing Hydrogen for the purposes of heating. 	<ul style="list-style-type: none"> Significant policy gaps remain with approximately 35% of targeted emission reductions lacking any clear policy or plan to facilitate them. Climate finance as well as coordination and support at the local and devolved levels is largely insufficient. Lack of detailed plans and proposals hinders real world action concerning building renovations in particular.
Opportunities for Improvement	Threats to Success
<ul style="list-style-type: none"> Implementation of equivalent 'sprint groups' could significantly aid in the delivery of climate action on the ground. 	<ul style="list-style-type: none"> Poor coordination with local level planning has left many local initiatives, attempting to achieve net-zero, highly dependent on Government action and decision making to be successful.

<ul style="list-style-type: none"> • Increased scenario modelling could help to better inform and speed up the decision-making process. • Continuing to build upon current ambitions will cement the UK as a world leader in facilitating climate action and drive the necessary change within the UK forward. • Providing increased levels of detail to support initial proposals will transform the UK's ambitions into more tangible, secure plans that are able to more reliably facilitate the transition towards Net-Zero, providing increased clarity for the population and business. 	<ul style="list-style-type: none"> • The slow pace of making major development decisions has increased the risks of under delivery on plans and increased transition costs nationwide. • The UK's novel approach exposes its plans to significant risk of failure with approximately 65% of all emission reductions supported by policy exposed to a least some risk. • Lack of any real detail regarding immediate actions to implement agreed plans risks the UK failing to facilitate significant real-world action. • A high reliance on the private sector comes with increased risk and thus the Government must be willing to adapt its approach to ensure the wider success of its strategy.
Transparency	
<p>UK Government plans surrounding building decarbonisation along with any subsequent policies and measures are comprehensively and concisely summarised and presented in full for the public to access.</p>	

4. French Government Strategy

4.1. Overview

Similarly to the UK, France has committed to achieving Net-Zero by 2050, pledging to do so on the very same day as the UK in 2019. To achieve this France has committed to decarbonising its buildings where the residential sector alone accounted for 28% of national emissions in 2017 and is noted to be currently lagging behind with regard to meeting emission reduction targets set in 2015 [13]. Previous decarbonisation efforts saw France outline its initial targets surrounding energy efficiency, renewables and emission reductions in its 2015 national low-carbon strategy, supported by France's pivotal 2015 Energy Transition Law. More recent efforts however, have seen revised plans and targets outlined in France's 'Integrated National Energy and Climate Plan for France' [14]. which was supported by France's updated 'National low-carbon strategy' [13] with both documents published in March of 2020.

4.2. Objectives

The following commitments and aims have been summarised from France's 2020 'National low-carbon strategy' [13], 2020 'Integrated national energy and climate plan for France' [14] and 2018 'Energy renovation plan for buildings' [15] all of which remain relevant in 2022.

Table 8: French Government commitments and target dates surrounding its wider aims and objectives.

Wider Aims	
Commitment	Target Date
Reducing total emissions from the buildings sector by 49% compared to 2015 levels.	2030
Eradicating fuel poverty.	2028

Defining more precise and ambitious objectives surrounding building decarbonisation.	Ongoing to meet other target deadlines
Encouraging energy sobriety through the evolution of education.	Ongoing to meet other target deadlines
Supporting innovation especially surrounding digital areas that could support building decarbonisation.	Ongoing to meet other target deadlines

Table 9: French Government commitments and target dates surrounding building energy renovations.

Building Energy Renovations	
Commitment	Target Date
Fostering a greater reliance on construction materials that are less carbonised and on equipment with increased environmental and energy performance.	Ongoing to meet other target deadlines
Accelerating the pace of renovation in the residential and tertiary sectors to reach 500,000 housing renovation per year.	2025
Ensuring the residential sector achieves 370,000 renovations per year in the short term before increasing to reach 700,000 in the longer term.	2022 (short term) 2030 (long term)
Improving the monitoring of energy renovations and access to data.	Ongoing to meet other target deadlines
Accelerating the skills development of the construction industry.	Ongoing to meet other target deadlines

Table 10: French Government commitments and target dates surrounding energy production and usage.

Energy Production and Usage	
Commitment	Target Date
Transitioning to rely exclusively on carbon-free energy sources. (in line with the wider 40% target for the share of renewable energies in final electricity consumption by 2030).	Ongoing to meet other target deadlines
Maximising the production of carbon-free types of energy that are adapted to various building types.	Ongoing to meet other target deadlines
Prioritizing the phasing out of oil and coal heating by completely removing it from government buildings.	2028
Reducing the energy consumption of the state's building stock by 15% compared to 2010.	2022
Facilitating the reduction in energy consumption across the buildings sector by 109 TWh compared to 2016 levels in line with the national target to reduce overall energy consumption by 32.5% by 2030.	2028
Reduce energy consumption across the buildings sector by 28%	2030
Ensuring 38% of final heat consumption comes from renewable energies.	2030
Maintaining 6.8 million air source heat pumps in single family homes and 2.2. million in multi-family dwellings to supply 45TWh of heat energy.	2028
Ensuring 65% of renewable and recovered energies are supplied through heat networks.	2030

4.3. Approach

To deliver on its commitments (tables 8-10) the French Government has outlined four primary guidelines, detailed below (table 11), to direct its approach towards decarbonising its buildings sector. It has also highlighted areas of concern for which current plans must be aware of and be willing to adapt to if they are to be successful.

Table 11: Stated guidelines and key steps and measures defining the French Government's approach towards building decarbonisation and delivering on its commitments alongside identified areas of concern [13],[14],[16].

<p><i>'Guide a change in the energy mix towards completely carbon-free energy consumption during the use phase of new and existing buildings'</i></p>	<ul style="list-style-type: none"> • Strategic guidelines are being consolidated through incentive pricing signals, the introduction of regionally relevant green house gas criteria to complement energy efficiency criteria, targeted grants for heating and domestic hot water systems that are highly energy efficient and use less carbonised energies and the inclusion of decarbonised energy objectives in the information on building energy performance. • Pressures on the resources required for carbon-free forms of energy are being considered leading to the use of better adapted carbon-free solutions for specific building types being prioritised. • High performance heat pumps complemented by joule effect systems and ,where appropriate, thermal solar and geothermal energy are being prioritised for individual housing to provide both heating and domestic hot water. • Heat networks utilising both renewable and recovered energies as well as high performance heat pumps complemented by joule effect systems and, where appropriate, thermal solar energy are being prioritised for collective housing to provide both heating and domestic hot water. • For overseas regions, thermal solar energy is prioritised to provide domestic hot water and reduce electricity demand with solar panels being utilised for other electricity needs. • The 2020 'Heat fund' pledges 350 million euros per year to support the implementation and development of heat networks, residual heat recovery, solar thermal technology and geothermal energy. The fund is regularly reviewed and is projected to amount to 3.46 billion euros between 2018-2028. • Additional financial incentives such as reduced VAT for heating networks and the support of the 2014 energy transition tax credit (CITE – which is now a subsidy) will support the generation of renewable heat.
<p><i>'Encourage the renovation of the whole existing residential housing stock and tertiary sector buildings to attain an average 'low consumption building' *** level across all housing and tertiary building stock'</i></p>	<ul style="list-style-type: none"> • France will implement its 'Building Energy Renovation Plan' to make energy renovation a national priority. The plan pledges 50 million euros to support low-income households every year, simplifies incentives, increases reliability of energy efficiency diagnosis, promotes better training and working standards and supports the large-scale renovation of public buildings with a budget of 4.8 billion euros. • To deliver on commitments regarding building renovations major investments delivered as part of the 'COVID-19 Recovery Plan' and 'Major Investment Plan' have been pledged to help support energy renovations for buildings especially for public buildings. • In the short to medium term energy 'sieves' (inefficient homes) will be targeted/removed where gains have the highest potential. • To reconcile the required acceleration in the scope of renovations, adequate incentives will be introduced that span nationwide. Incentives include guaranteed high levels of performance, in terms of energy

	<p>efficiency, for the renovation actions, contained expenditure that avoids partial renovations that could prove difficult to fully renovate and strengthened support for households whilst optimising renovation work.</p> <ul style="list-style-type: none"> • Renovation and insulation products that use the least carbon and contribute towards storing atmospheric carbon in buildings are to be developed further. • Incentives will be provided appealing to the desires of improving home comfort i.e. summer comfort, air quality, natural light etc. • From 2022, the Rénov' aid programme will seek to group property renovation benefits into a single programme which also provides support and information to property owners looking to renovate. The programme comes with its own national website and telephone number enabling nationwide support through a free public service. • Research and innovation in areas surrounding knowledge on current building stock, required new low-carbon technologies and optimising renovation objectives will see continued support. Thermal efficiency objectives in particular will be defined based on building type and aim to reconcile the cost of renovation with achieving high performance insulation of the building. • Programmes aiming to support an increase in the skills surrounding building decarbonisation will be developed and maintained along with products and services for renovations with the latter eventually offering concrete guarantees on energy results. • Results monitoring for renovations and incentive measures will be improved. • Examples will be set by enabling significant performance renovations in public buildings. • Overseas building renovations will seek to reduce the need for air conditioning by protecting buildings from sunlight.
<p><i>'Improving the energy and carbon performance levels of new buildings in future environmental regulations'</i></p>	<ul style="list-style-type: none"> • Future regulation will allow for high performance building insulation and the development of the use of renewable energies. • Life cycle analysis will be used to introduce building greenhouse gas and building envelope criterion, allowing for a reduction in a building's energy requirements due to its design. For example, France's new bioclimate standard requires a 30% improvement in the performance of a building's envelope compared to requirements from the previous RT2012 standard. • Efforts will focus on reducing the need for air conditioning by using nature-based solutions to improve summer comfort, an area of increased focus given the recent rise in unpredictable summer weather. • Future building regulations will seek to promote less carbonised construction materials and equipment with higher environmental performance such to meet new performance objectives that consider the carbon footprint of a building throughout its life cycle. • Future regulations surrounding new buildings must improve carbon reservoirs by enabling the increased storage of atmospheric carbon within building materials. • The above points have been largely fulfilled by France's RE2020 regulation which came into force in 2022 and notably seeks to facilitate a 52% reduction in embodied carbon for new builds by 2031.

'Aiming for more energy efficient equipment and moderated use'	<ul style="list-style-type: none"> • The roll out of smart technologies for controlling demand will be advanced to help reduce the electricity consumption of electrical equipment. • Lifestyle and consumption changes tailored towards improved energy consciousness will be promoted through information and awareness campaigns, urging households to cut down on electricity usage.
Identified Areas of Concern	
<ul style="list-style-type: none"> • The required pace of building renovation such to meet current targets is highly ambitious. • Enabling the renovation of all existing buildings to achieve 'low consumption building' *** level requires significant investment and management to be successful. • Renovation and construction must pay close attention to its impacts on areas such as air quality, resource consumption, biodiversity, waste and landscape preservation. • Renovations must also ensure to preserve micro-environments that support local biodiversity within buildings. 	

*** To achieve 'low consumption building' standard energy consumption must be below 50 KWh/m² per year.

4.4. Critique and Recommendations

Following the release of the French Government's 2020 proposals to decarbonise its buildings sector the International Energy Agency (IEA) released its 2021 policy review assessing France's approach to building decarbonisation [16]. The conclusions of this assessment and that of the Climate Transparency's 2021 report covering France [17] have been summarised below (table 12).

Table 12: IEA and Climate Transparency critique and recommendations concerning policy, delivery and next steps with regard to France's 2020 'National low-carbon strategy' and 'Integrated National Climate Energy Plan for France' [16], [17].

Critique	
Policy	<ul style="list-style-type: none"> • Since 2015 France has done much to strengthen its building regulations for new buildings and existing stock highlighting France's willingness to improve and expand upon its previous plans. • France's COVID-19 Recovery Plan, amongst other schemes, remains an exceptional scheme to drive forward decarbonisation efforts in the building sector and provides lessons to other countries. • 2030 targets within the building sector are compatible with ambitions to keep global warming limited to 1.5°C. • Policies still remain insufficient in areas regarding the integration of regulatory frameworks to support system wide regulations and measures, often leaving administrative process overcomplicated.
Delivery	<ul style="list-style-type: none"> • In 2021, France installed more heat pumps than any other country in the world. • France's comprehensive monitoring criteria allows for under delivery to be quickly identified and quantified, increasing the speed and tailored nature of retaliatory measures. • France's building related emissions per capita remained 0.82 times the G20 average in 2020 and fell to only 0.79 in 2021 highlighting the high level of electrification of the building sector with low-carbon electricity. Furthermore, France has been able to decrease building related emissions significantly faster than the G20 average (17% compared to 3% for the period covering 2015-2020). • Considerable delivery gaps exist across the buildings sector largely due to lack of administrative staff and lengthy procedures.

	<ul style="list-style-type: none"> • Past performance trends are insufficient to meet building decarbonisation targets with the building sector having missed its first carbon budget share by 14%. • Overall progress regarding the renovation of existing buildings has been marginal as a result of noted structural barriers. Such barriers include insufficient awareness of the issues associated with reducing energy consumption and separate regulatory standards. • France's High Council on Climate found that only 0.2% of all renovations were providing tangible increases in energy efficiency. • France's high reliance on sobriety will need to be supported by lasting behavioural changes.
<i>Outlook</i>	<ul style="list-style-type: none"> • Policies surrounding building decarbonisation are extensive and remain compatible with limiting global warming to 1.5°C. • Administrative processes remain overly laborious and significantly hinder the implementation of otherwise strong policy. • France's ever improving support schemes remain world leading although further support surrounding delivery will be needed to translate France's significant ambitions concerning building energy renovations.
<i>Recommendations and Next Steps</i>	
<ol style="list-style-type: none"> 1. Review energy efficiency progress and strengthen measures and funding cost-effectively to ensure 2030 energy efficiency goals are achieved. 2. Accelerate the renovation of existing buildings in the residential sector and all public buildings and assess the effectiveness of support schemes currently in place. 3. Simplification of pathways for citizens to access available subsidies for renovation, possibly through a dedicated public investment bank, could be a useful tool for improving building renovation. 4. Improve the effectiveness and enhance the synergies between regulatory frameworks surrounding buildings and other sectors to simplify administrative procedures and improve the Government's capacity for policy implementation. 5. Ensure the continued support for policy measures that facilitate long-term changes in the energy usage behaviours of the French population i.e. switching off devices, capping energy usage etc. 	

4.5. Regional Approaches

As with section 3.5, this section shall discuss several regional approaches within France where particular initiative has been shown and opportunities are presented for improving upon France's building decarbonisation strategy. Such opportunities may also provide opportunities for other developed nations to better formulate their own approaches towards building decarbonisation and ensure their wider climate targets are met.

4.5.1. Paris

Due to the high population density within Paris, its residential and service sectors contributed 80% towards the overall energy consumption of the city whilst also making up over 20% of its carbon footprint in 2018 [18]. As a result, the decarbonisation of Paris' buildings sector is identified as a major component of its overall drive towards a net-zero city by 2050. Paris's plans for decarbonising its buildings are outlined within its 2018 'Paris Climate Action Plan' [18] which highlights the significant steps the city of Paris is taking to implement new environmental measures whether it be surrounding renovations, the pioneering of new technologies or the commissioning of entirely new carbon free districts.

- **Regional Plans** in Paris have been ambitious and extensive in the past, facilitating the renovation of 30,000 social housing units and 300 schools with a further 50,000 dwellings in jointly owned properties having received support for their renovations between 2018-2020 [18]. More recent plans have identified that 70% of remaining buildings are

particularly energy inefficient prompting the Paris authority to set a target to renovate 100% of all existing building stock by 2050 ensuring all buildings become compatible with very low energy consumption standards. Achieving such standards across the existing building stock aims to bring down energy consumption by one third by 2030 and by one half by 2050 compared to levels in 2004 (figure 7). Such a target will require the completion of 40,000 renovations across private dwellings per year, a task that the city of Paris will attempt to finance through the use of third-party financing to reduce the load on public funds with reimbursement to homeowners delivered via energy savings [18]. Additional efforts such as the reinforcement of control on the limitation of the use of night-time lighting and other behavioural changes will also help to ensure that Paris' climate transition encompasses the energy usage practises of its population as well as the performance of its buildings.

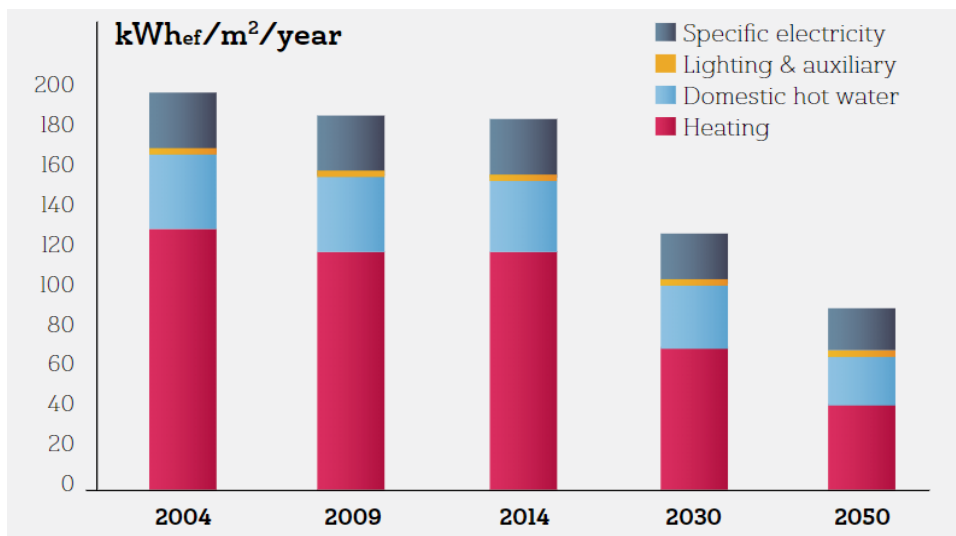


Figure 7: Projected total energy consumption across Paris between 2004-2050 if current plans to reduce energy consumption are successful [18].

- Pioneering New Technologies** has helped drive Paris' decarbonisation efforts with the use of cutting-edge CO₂ measurement and tracking techniques providing the Paris authority with real time CO₂ measurements spanning across up to 35 million buildings and companies [19]. Having such a tool to accurately identify emission sources across the city of Paris will aid the local authority in its decisions regarding areas to prioritise and implement new environmental measures, how best to inform the population about high emission zones and how best to optimise decarbonisation efforts to ensure plans are being implemented as cost-effectively as possible. This, amongst other technologies, will become ever more essential in enabling the transition of cities, towns and nations toward net zero by helping Governments and organisations more efficiently and cost-effectively tackle the challenges associated with building decarbonisation, challenges which previous practises and technologies remain largely ineffective at solving. As such Paris' adoption and use of such a technology provides an example to the French Government and indeed other Governments as to the benefits of furthering innovation and research and nurturing the use of innovative techniques to tackle novel problems both regarding building decarbonisation and wider decarbonisation efforts.
- New Building Practises** across France have encouraged the use of less carbonised materials and equipment with better environmental performance such to reduce the embodied carbon associated with building construction (table 11). Taking the first major

steps in this regard, Paris has commissioned the designing and building of France's first zero carbon district, which will be built in line with such ambitions [20]. For instance, the district will be built using energy comprised of 65% renewable energy with 50% of this energy being produced or recovered on site. Furthermore, the entire project seeks to reduce its overall carbon footprint down to a fifth of what it would have been following older practises [20]. Such a project is testament to Paris' ambitions and an example of Paris leading from the front with regard to translating plans and policies (guided by life cycle analysis) into tangible changes towards more environmentally conscious building practises. Additionally, such a project aims to demonstrate the benefits that come from reconciling technical innovation with low-carbon engineering setting a precedent for other countries to come up with their own innovative low-carbon engineering solutions to drive forward their climate transition.

4.5.2. Lyon

Following the election of new members to Lyon's metropolis council, members agreed on a new 3.6 billion euro plan covering the period 2021-2026 which aims to facilitate the recovery and ecological transition of Lyon. Such a transition is stated to be guided by three main principles: ecological transition, solidarity and partnerships [21]. To this end, Lyon has taken significant steps in delivering upon such commitments, working closely with the population of Lyon and other private organisations to bring about widespread urban reforms and formulate new ways of building, heating and cooling which do not contribute so heavily to regional emissions [21].

- **Regional Plans** set four primary building energy objectives for the period 2021-2026 including the 20% reduction of energy consumption across Lyon, the doubling of the share of renewables and recovered energies in the energy mix, a tenfold increase in solar energy production and a further threefold increase in the number of homes supplied by the district heating network. As part of the pledged 3.6 billion euros, 25 million euros will be used to support efforts to achieve these targets with 9 million supporting the implementation of a new heating network, 4.7 million supporting the extension of existing heat networks, 6.2 million to support solar panels on roofs and the rest pledged to help recover waste heat [21]. Furthermore, additional investment of 4 million euros will go towards tackling air pollution with schemes aiding individuals to change their older inefficient fireplaces set to be reinforced and further supported by the development of a territorial atmosphere protection plan (PPA) [21]. Such plans are heavily supported by the private sector (partnership principle) enabling immediate change to be implemented and innovative approaches to be widespread (such as the return of mud bricks [22]).
- **Local Collaboration** has been the spearhead of Lyon's efforts to implement change with a total of 59 groups consisting of neighbouring communities, residents, the private sector and research institutions working together to drive Lyon's ecological transition [21]. To this end, urban planning operations are managed across the local council, the private sector and the local inhabitants fostering a stated 'participatory approach of co-construction and citizen involvement' [22]. Such an approach has helped to ensure that local targets and ambitions are guided by the sentiment of the population and that subsequent action is supported by all with environmental solidarity unifying efforts and amplifying Lyon's capacity to implement environmental measures. For example, urban development projects in Lyon Confluence (controlled by private development firms) have promoted the use of energy consumption control tablets for occupants to use, enabling users to monitor and adopt improved habits for reducing energy consumption. The corresponding usage data is sent to a community energy management system which then analyses the data and adapts energy supply to better meet demand [22]. This provides an example of where collaboration

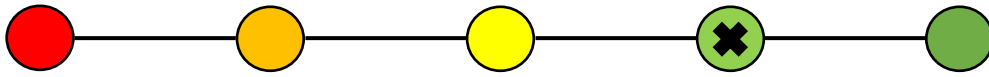
has helped to foster an almost symbiotic approach to building decarbonisation, with the private sector making money to enable the population to have more control over their climate impact which supports the local authority to foster environmental sobriety and meet its decarbonisation targets.

4.6. Summary



Table 13: Overall summary of the French strategy to decarbonise its buildings.

French Government Heat and Buildings Strategy	
Strengths	Weaknesses
<ul style="list-style-type: none"> • France's building decarbonisation targets remain highly ambitious and compatible with limiting global warming to 1.5°C. • Government support schemes stand as a global example of how to facilitate building decarbonisation, providing comprehensive support and ensuring ambitions can be implemented in the real world. • Increased autonomy at the regional level and reliance on private finance has allowed local authorities to enact their building decarbonisation initiatives without the need of increased Government support. • Comprehensive monitoring criteria has allowed the French Government to effectively monitor progress and quickly identify issues and implement changes. 	<ul style="list-style-type: none"> • Overly laborious administrative processes, brought about by a lack of integration between regulatory frameworks and limited whole-system approaches, have limited the impact of many previous support schemes subsequently hindering delivery efforts. • Lack of awareness surrounding delivery issues and new regulations has further hindered delivery efforts and compromised the achievement of building decarbonisation targets.
Opportunities for Improvement	Threats to Success
<ul style="list-style-type: none"> • The increased use of new technologies and novel approaches could significantly aid the delivery of building decarbonisation measures by revealing better optimised delivery methods and decision-making processes. • New building practises, pioneered at the local level, could reveal new optimal methods that can be scaled up to national level building projects, ensuring that significant green renovations do not overly contribute to national emissions and environmental harm. • Local collaboration between the authorities, the population and the private sector could greatly amplify regional capacity to implement new environmental measures whilst also helping to foster a greater sense of environmental sobriety. 	<ul style="list-style-type: none"> • High reliance in many areas on energy sobriety needs to be supported by improved information campaigns to keep the public informed and foster long lasting behavioural changes across the population. • Past levels of performance across the buildings sector are insufficient to meet existing targets thus highlighting the need to simplify administrative procedures quickly to increase the effectiveness of support schemes and close delivery gaps. • High reliance on private investment will need to be supported by increased policy certainty and further measures to stimulate future investment.
Transparency	



French Government plans surrounding building decarbonisation along with any subsequent policies and measures are comprehensively outlined in full for the public to access however objectives and other information could be more concisely summarised.

5. Dutch Government Strategy

5.1. Overview

The Netherlands has committed to transitioning to almost Net-Zero (~95% reduction in equivalent CO₂ emissions) by 2050 with an additional medium-term target of cutting overall emissions by 49% by the year 2030 (a target noted to likely increase to 55% in the coming years [23]). To this end, the Netherlands' Senate approved the 'Climate Act' of May 2019 enshrining into law the long-term objectives of climate policy for 2030 and 2050 as well as further committing the Dutch Government to formulating updated climate plans every five years. With regards to buildings, annual emissions across the built-up environment amounted to 24.6 Mton CO₂ equivalent in 2017 (or 12.4% of total emissions) with total energy consumption amounting to 30% of the national total [24], highlighting the importance of decarbonising the seven million-plus homes and millions of other buildings that currently exist within the Netherlands. In its most recent proposals, the Dutch Government has outlined agreed plans to decarbonise the nation's buildings within its November 2019 'Integrated National Energy and Climate Plan' [24] where commitments stated in its June 2019 Climate Agreement [23] are addressed and plans for achieving set targets are detailed.

5.2. Objectives

The following aims and commitments have been summarised from the Dutch Government's 2019 'Integrated National Energy and Climate Plan' [24] and 2019 'Climate Agreement' [23] both of which remain relevant in 2022.

Table 14: Dutch Government commitments and target dates surrounding building energy renovations.

Building Energy Renovations	
Commitment	Target Date
Increasing the pace of sustainability efforts by insulating 200,000 existing homes per year and making them natural gas free.	2030
Ensuring a reduction of 3.4 Mt of CO ₂ in the built environment such that maximum annual CO ₂ emissions do not exceed 15.3 Mton.	2030
Approximately 1.5 million homes and 15% of non-residential buildings and social real estate will be made more sustainable and CO ₂ emissions in existing non-residential buildings will be cut by an additional 1 Mt.	2030
Enabling the 70% reduction in CO ₂ intensity of the heat supplied compared with pre-existing central heating boilers.	2030
Implementing a multi-annual mission-oriented innovation programme (MMIP) with the aim of accelerating energy renovation in the built-up environment (targeting enthusiasm of property owners and users with regard to energy renovation and increased digitisation).	Ongoing to meet other target deadlines.
Bringing housing cost neutrality (where the costs associated with improving increasing sustainability are recouped via energy bill savings) within reach for a larger number of households.	Ongoing to meet other target deadlines.

Table 15: Dutch Government commitments and target dates surrounding energy production and usage.

Energy Production and Usage	
Commitment	Target Date
Transitioning the built-up environment to rely more heavily on natural gas free alternatives such as heat pumps, residual heat or geothermal energy for heating and hot water.	Ongoing to meet target deadlines.
Reducing natural gas extraction from the Groningen field to zero.	2030
Enabling the small-scale generation of renewable electricity from solar roof panels to reach 10TWh.	2030
Imposing renewable source requirements on the heat supplied to homes with requirements being periodically tightened so that heat supplied will be generated entirely by renewable sources by 2050.	Ongoing to meet other target deadlines.
Achieving a primary energy consumption of 1950 petajoules (final energy consumption of 1837 petajoules) such to contribute towards the wider European target of achieving 32.5% energy savings by 2030.	2030
Adopting measures to facilitate 1.3 petajoules worth of energy savings across Government real estate.	2030
Ensuring 20% of local energy consumption in the built-up environment is generated from renewable sources.	2030
Implementing multi-annual mission-oriented innovation programmes (MMIPs) with the aim of supporting renewable heating and cooling (targeting heat pumps, heat batteries, large scale thermal storage and tap water systems) as well as increased electricity production, security and electrification of the energy system in the built-up environment.	Ongoing to meet other target deadlines.

Table 16: Dutch Government commitments and target dates surrounding its wider aims and objectives.

Wider Aims	
Commitment	Target Date
Ensuring that consumers are able to optimally benefit from competition in the energy market and are able to make their own choices and receive the subsequent remuneration for investments.	Ongoing to meet other target deadlines.
Creating a fully circular economy by 2050 (at least 80%) with an immediate target to reduce primary raw material consumption (in areas such as building construction) by 50%.	2030
Improving home air quality to meet WHO recommended values.	2030
Implementing a multi-annual mission-oriented innovation programme (MMIP) with the aim of developing a new energy system for the built-up environment (targeting local system optimisation, control algorithms for savings and energy optimising and sector coupling).	Ongoing to meet other target deadlines.

5.3. Approach

To deliver on its commitments (tables 14-16) the Dutch Government has outlined four broad guidelines, detailed below (table 17), to direct its approach towards decarbonising its buildings sector.

Table 17: Stated guidelines and key steps and measures defining the Dutch Government's approach towards building decarbonisation and delivering on its commitments [24].

<p><i>‘Sliding scale energy taxation’ and ‘Funding’</i></p>	<ul style="list-style-type: none"> • Energy tax has been adjusted to create a greater incentive for increased sustainability, raising tax on natural gas and reallocating the acquired funds to decrease it for electricity (appendix B [10]). Such a move seeks to benefit households over companies by reducing energy bills and supporting low-income households in particular. • 425 million euros has been made available by the Government to help further bring down energy bills. • Energy tax increases will be reviewed in 2023 to assess whether it remains necessary to maintain the current level of sustainability incentives. • It is recognised that providing a wide array of appealing financial instruments, for investment in sustainability, is crucial to decarbonise the Netherlands’ built-up environment. • Up to and including 2030, 50-80 million euros of resources will be provided by the Government annually as part of its ‘Heat Fund’. Such a fund seeks to prevent over-crediting and has the potential to grow through additional supplements from private funds. • The previous ‘Investment Grant for Sustainable Energy’ (ISDE) has been expanded to encompass more than just the installation of heat pumps such that a subsidy can now be requested for home insulation. The Government has pledged 100 million euros annually up until 2030 to fund this expansion. • The ‘Subsidy for Energy Savings at Home’ (SEEH) has been recently merged with the ISDE and has provided 90 million euros between 2019-2020 to owner-occupiers to help support them over the short term in making their homes more sustainable. • The ‘Energy-saving Measures Programme’ (PRE) pledges funds to support smaller measures that can be implemented in homes, such as better heating control and radiator foil, that help to quickly and cheaply reduce CO₂ emissions. • Existing policies facilitate the reduction of VAT from 21% to 6% for applying insulation material and glass.
<p><i>‘Making homes more sustainable’</i></p>	<ul style="list-style-type: none"> • A district-oriented approach is being used in which residents and building owners can get involved in making their district more sustainable with efforts managed by the municipality. • Testing grounds for natural gas free districts have been started back in 2018 to learn more about what preconditions are needed to facilitate further scale up of natural gas free regions. 400 million euros has been made available for this purpose. • The association of Dutch municipalities has launched a knowledge and learning programme to support municipalities through knowledge and experience sharing. • 200 million euros has been allocated for the period 2020-2023 to connect 100,000 rented homes to the heat grids and provide them with heat pumps. The similar nature of the selected properties is noted to make them ideal candidates to kick off building renovation efforts. • Schemes such as the ‘Renovation Accelerator’ and discounted ‘Landlord Levy’ provide support for housing associations looking to make their housing stock more sustainable with 130 million allocated annually up until 2024 for the ‘Renovation Accelerator’ alone. • Further incentives are being rolled out to encourage landlords to renovate their properties with agreements already in place to facilitate

	<p>the making of 300,000 existing homes and other buildings more energy efficient each year.</p> <ul style="list-style-type: none"> • Digital platforms and new standards are being developed to ensure owner-occupiers are provided an insight into the possibilities and financial support available regarding increasing the sustainability of their homes. Additional energy efficiency awareness campaigns such as 'Now's the time to make energy savings' also seek to increase environmental sobriety and raise awareness. • New buildings are constructed in almost all cases without a gas connection and must classify as a 'Nearly Zero-Energy Building' (NZEB). • Financial incentives are already in place to encourage consumers to make their properties more sustainable. Incentives include VAT refunds on the purchase of solar panels, higher borrowing limits for people who implement energy saving measures and house price reductions for the buyer if the property possesses at least an A++ energy label. • Development of 100% high-quality reuse of available concrete seeks to support a circular root for the use of raw materials involving in building construction. • A dedicated MMIP covering 'Accelerating energy renovation in the built-up environment' seeks to support Government efforts to implement the widespread home renovations needed to meet its ambitious renovation targets (table 14).
<p><i>'Making non-residential buildings more sustainable'</i></p>	<ul style="list-style-type: none"> • A comprehensive set of standards and support has been introduced to help make existing commercial and social real-estate more sustainable. In 2021 for example, the Government introduced a legal energy performance standard for buildings in line with current 2030 and 2050 targets (tables 14-16). • The 'Sustainable Social Real Estate Knowledge and Innovation Platform' will support social sectors in developing roadmaps outlining the steps they will take to transition towards low CO₂ real estate. • In 2023 any office larger than 100 m² must possess an energy label of C or above or else it will cease to be used as an office.
<p><i>'Sufficient renewable heat supply'</i></p>	<ul style="list-style-type: none"> • The 'Sustainable Energy Production Incentive' has been expanded to include sustainable heat making it eligible for increased support. • Central government has pledged additional support in the form of supporting the Green Gas sector, amending the 'Heat Act' and developing geothermal energy through additional reinforcement and acceleration measures. • The development of electricity-to-gas technologies coupled with increased electrification (from renewable sources) through encouraged offshore wind development and renewable energy production on land (amounting to 49TWh and 35TWh respectively) seeks to ensure a secure supply of heating energy is available. • Further integration into the EU electricity market aims to guarantee energy supply in a system that is currently transitioning to become entirely net-zero. • MMIPs covering 'Renewable electricity generation on land and in the built-up environment', 'Renewable heat and cooling in the built-up environment', 'A robust and socially supported energy system' and 'Electrification of the energy system in the built-up environment' seek to provide more information and outline methods surrounding ways

	that a sufficient and secure energy supply for the buildings sector can be guaranteed.
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5.4. Critique and Recommendations

In response to the release of the Netherlands' 2019 'Integrated National Energy and Climate Plan' [24] the European commission conducted its assessment of the released building decarbonisation plans in 2020, highlighting pros and cons and making subsequent recommendations [25]. The assessments conclusions together with that of the IEA's independent 2020 assessment of the Dutch Government's proposals [26] have been summarised below (table 18).

Table 18: IEA and European Commission critique and recommendations concerning policy, delivery and next steps with regard to the Netherlands' 2019 'Integrated National Energy and Climate Plan' [25], [26].

<i>Critique</i>	
<i>Policy</i>	<ul style="list-style-type: none"> • Strong steps have been taken to improve energy efficiency in buildings with new measures encouraging energy efficiency renovations of existing buildings and a transition away from natural gas. • Numerous financial and resource support schemes are in place to support the decarbonisation of buildings although more support for municipalities is needed to ensure they are able to formulate and execute their own decarbonisation plans. • National contributions in reducing final energy consumption are deemed modest with the EU expecting more to be done to facilitate increased energy savings. • Policy gaps exist in areas surrounding how recently identified hurdles preventing the implementation of plans will be addressed. • Plans fail to explain how the Netherlands' 'energy first principle' will be applied in practise. • The promising new framework for research and innovation has facilitated five new MMIPs that directly support building decarbonisation efforts. • More work needs to be done to translate the great potential of Hydrogen and biomethane for decarbonising buildings into appropriate policy.
<i>Delivery</i>	<ul style="list-style-type: none"> • With a shift in focus towards CO₂ emission reductions, energy efficiency measures risk not being implemented as a result of specific barriers such as their more disruptive nature. • An observed high level of collaboration between stakeholders is encouraging however work must be done to address key barriers to success such as spatial planning, social acceptance and costs. • Renewable heat supply issues are increasingly likely following the closure of the Groningen gas field resulting in a growing dependence on natural gas imports and as such the Government must work harder to reduce demand, decarbonise its gas supply and retrofit its gas infrastructure. • Lack of detailed plans and Government guidance is hindering the ability of individual sectors to contribute towards national energy efficiency targets. • Poor monitoring of the impacts of various measures promoting energy efficiency makes issue diagnosis difficult and any response slow and inefficient. • There remains a lack of a clear timetable for the implementation of policies and measures.
<i>Outlook</i>	<ul style="list-style-type: none"> • Initial plans released in 2019 go a long way in outlining how the built-up environment will be decarbonised with measures and policies supporting clear targets surrounding energy efficiency/usage, material usage, and renovations. Subsequent policy however, does not do enough to expand upon ambitions and address newly identified delivery barriers.

	<ul style="list-style-type: none"> • Unique risks to the Dutch energy supply regarding the closing of its Groningen natural gas field places additional pressure on the Government's plans (in areas relating to renewable energy supply specifically) that the Government must be willing to adapt to such to ensure its climate plans are successful. • Lack of detailed plans and support has resulted in increased incoherence nationally with many sectors remaining unsure on their individual roles in ensuring national climate targets are met and many local authorities struggling to formulate and implement their own building decarbonisation initiatives.
Recommendations and Next Steps	
<ol style="list-style-type: none"> 1. Design additional policies to tackle identified and anticipated hurdles in the way of meeting 2030 climate targets for the built-up environment through further consultations with stakeholders, ensuring previous plans are adapted and continue to be relevant. 2. Provide clear guidance and define clear roles for each energy sector to better coordinate the transition away from natural gas and inform sectors of their role in meeting national climate targets. 3. Improve monitoring and analysis of the impacts of the 'Climate Agreement' [23] and other policies and measures to aid tracking the Netherlands' climate transition as well as reformulating and adapting future climate strategy. 4. Strengthen feedback mechanisms to ensure the new findings from the Netherlands' promising innovation programmes are able to guide future policy and help improve building decarbonisation measures. 5. Continue to support early-stage development of emerging technologies and MMIPs that have the potential to cost-effectively reduce emissions across the buildings sector and further stimulate private investment. 6. Increase assistance for local authorities to support them in formulating and implementing their own regional decarbonisation strategies by providing additional financial resources, training and opportunities to share information with each other. 	

5.5. Regional Approaches

This section shall outline regional approaches within the Netherlands where particular initiative has been shown towards building decarbonisation and environmental planning in general. Such approaches towards building decarbonisation may once again present opportunities to the Dutch Government, amongst others, for improving upon their current plans and better delivering upon their climate commitments going forward.

5.5.1. Amsterdam

In 2020 the city of Amsterdam would release its 'New Amsterdam Climate Neutral Roadmap' [27] in which it would commit itself to achieving near climate neutrality by 2050 (in line with Government targets) with more intermittent CO₂ emission reduction targets of 5% and 55% reductions by 2025 and 2030 respectively [28]. To achieve this the local authority aims to reduce the 14% contribution that heating has towards overall city emissions by ensuring that all 650,000 homes within Amsterdam, amongst other buildings, possess sustainable forms of heating by 2040 with further steps being taken to reduce the additional 11% contribution associated with buildings [28]. More recently, the city of Amsterdam has released an update on its plans in the form of its 'New Amsterdam Climate Roadmap Report 2021' [28] in which steps taken between 2020 and 2021 towards building decarbonisation have been discussed. Such steps highlight the significant work the city has undertaken towards implementing a whole-system approach towards heating homes and the realisation of a circular economy as well as its commitment to stimulating increased Government support and leading by example.

- **Regional Plans** have enabled significant progress in recent years with an additional 8000 homes connected to Amsterdam's heat distribution network in 2020 alone [28]. In addition to this, the cities newly implemented 'Sustainable Recovery Plan' plans to invest 78 million

euros between 2020-2025 in a wide range of measures to reduce unemployment and boost the sustainability of the city. Such measures cover building renovations, insulation, accelerating the phasing out of natural gas in homes and installing additional solar panels on roofs to expand upon the 124MW worth of solar panels already installed in homes [28]. Current plans are estimated to bring emissions down by an estimated 37% by 2030 (figure 8), a figure still short of the 55% required by 2030 highlighting the need for additional actions and measures. It is noted by the city authority however, that such increased efforts will require increased Government intervention with regional plans relying on tougher national and international measures to be successful, measures that would also be welcomed by the 75% of Amsterdam citizens that currently support the transition towards a more sustainable city [28].

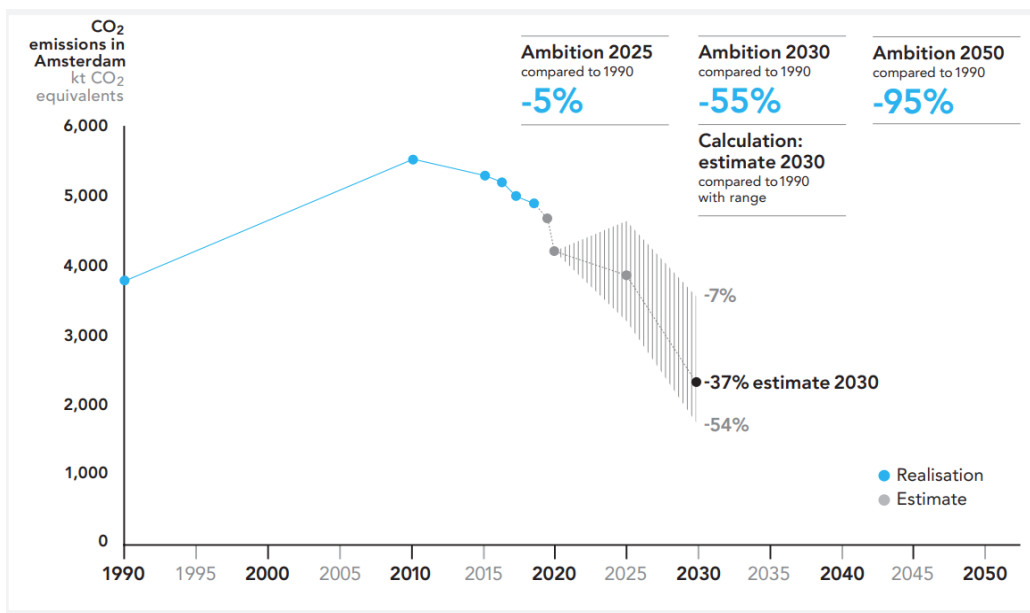


Figure 8: Past and projected CO₂ equivalent emissions for the city of Amsterdam together with emission targets [28].

- Developing Citywide Heating Infrastructure** has been a major focus of Amsterdam's building decarbonisation strategy with a whole-system approach enabling energy sources from the local surroundings to be utilised more efficiently and effectively than possible if homes were heated on an individual basis. To this end, it is noted that new sources of heat will need to be implemented into the heating grid in order to supply sufficient energy to heat all buildings sustainably by 2040. Identified new sources include geothermal, aquifer thermal energy systems (in which the heat from Amsterdam's water system is utilised) and waste heat from industry with each being the focus of subsequent pilot studies to assess feasibility and potential capacity. Preliminary results show Amsterdam's water systems alone to possess enough heat to meet 2040 heating targets [28]. This multi-pronged approach has provided options and redundancy for Amsterdam's citywide heating plans whilst also enabling the results of innovation and research to be used effectively to accelerate decarbonisation efforts.
- Challenging the Market** has seen the city of Amsterdam take the initiative with regard to its climate plans, implementing measures and requirements wherever possible to encourage the adoption of more sustainable practices and fill as much as possible the policy gaps left by the Dutch Government. For instance, the city of Amsterdam has challenged the market with eight new tenders delivering only energy-neutral and energy producing buildings,

furthering the cities climate ambitions whilst attracting support from the private sector [28]. Furthermore, new measures have ensured all new-build homes will be free of natural gas and that steps will be taken to ensure that in the future only energy-neutral/producing construction methods will be used helping to support the Dutch Government's ambitions of a circular economy. Additional efforts continue to show Amsterdam to be exceeding current Government action in any way it can whilst providing clear requirements from the Government regarding what new measures need to be implemented to ensure Amsterdam's longer-term plans are successful. As such, Amsterdam's approach provides an example for the rest of the Netherlands concerning how building decarbonisation can be facilitated in the current climate and how the Government can be supported in making the required decisions to ensure the wider success of regional initiatives (an area identified by the IEA as in need of improvement (table 12) [26]).

5.5.2. Rotterdam

Signed in 2019, the 'Rotterdam Climate Agreement' [29] represents the culmination of efforts from over 100 private companies and social organisations across Rotterdam with over 1000 participants taking part in its creation. Detailed within are a total of 49 climate deals, 13 of which directly relating to building decarbonisation, that outline how Rotterdam's plans to reverse the previous upward trend of its CO₂ emissions before reducing them by 49.6% by 2030 (compared to 2017 levels) will be achieved. To this end, responsibilities have been split across six so called 'Climate Round Tables' covering Port and Industry, Clean Energy, Mobility, Built Environment, Circular and Healthcare [29], a system not dissimilar from the UK's Oxford 'Sprint Groups' and 'Zero Carbon Oxford' collaboration [9] (section 3.5.1) reaping many of the same benefits.

- **Regional Plans** within Rotterdam regarding building decarbonisation have been summarised in 13 of its climate agreements where Bouwinvest, Manhave, Havensteder, Hoek van Holland, Ressor Wonen, Vesteda, Woonbron, Onze Woning and Woonstad Rotterdam property organisations have pledged to ensure their existing building stock become natural gas free and more sustainable by 2045. Furthermore, other homeowner's associations have committed to implementing new energy measures and preparing their building stock for a future without natural gas [29]. Each of the organisations stated above will work collaboratively to deliver on their commitments with progress and support being monitored for all members of the built environment 'round table' to ensure plans are on track to meet wider regional targets. Progress towards meeting these commitments will see 15,000 homes be made more sustainable with 10,000 taking steps to be made free of natural gas by 2045 [29]. In addition to these climate deals, it is also intended to produce a sustainability toolbox for real estate agents to inform their customers about relevant sustainability information and help stimulate the energy transition [29].
- **Climate Round Tables** form the organisational structure of Rotterdam's decarbonisation initiative and succeed in compartmentalising efforts towards decarbonising the various areas of Rotterdam's economy. As previously mentioned, such a scheme delivers many benefits also seen in the UK's Oxford 'Sprint Groups' [9] (section 3.5.1) namely the ability to consolidate expertise, better allocated resources and effectively divide responsibility amongst those who are best suited to tackle particular issues. As with 'Zero Carbon Oxford' [9] the 'Climate Round Tables' also coordinate collaboration between a large number of stakeholders which in turn greatly increases the capacity of the local authority to execute its decarbonisation plans, a reality that the IEA points out has remained a challenge for the Dutch Government to realise (table 18) [26]. As such, going forward the Dutch Government could seek to further compartmentalise its decarbonisation efforts to ensure that plans and efforts surrounding building decarbonisation, as well as other areas, are formulated and

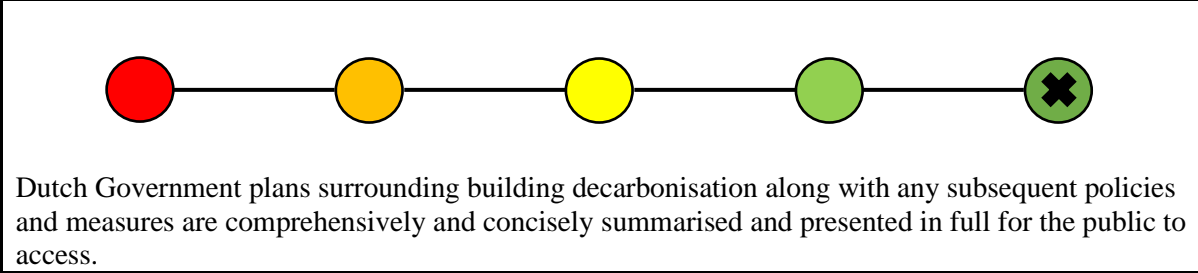
presented by an increasingly dedicated team of relevant experts, companies and other organisations.

5.6. Summary



Table 19: Overall summary of Dutch Government strategy to decarbonise its buildings.

<i>Dutch Government Heat and Buildings Strategy</i>	
<i>Strengths</i>	<i>Weaknesses</i>
<ul style="list-style-type: none"> • A strong package of measures has been outlined with numerous financial support schemes aiding home renovations and the wider transition away from natural gas. • Comprehensive research and innovation programmes (MMIPS) lay a strong foundation for new approaches surrounding building decarbonisation to be discovered, implemented and improved upon. • High levels of collaboration between the Government, local municipalities and the private sector is encouraged which should help to coordinate national efforts. 	<ul style="list-style-type: none"> • Current policies are insufficient to tackle many newly identified delivery hurdles. • Support for local plans and initiatives is insufficient. • Plans do not go far enough to explore the potential of certain key technologies such as Hydrogen for building decarbonisation. • Plans lack a clear timetable and the required level of detail to effectively coordinate national efforts and facilitate intended levels of collaboration. • Ambitions could go further especially regarding reductions in energy consumption.
<i>Opportunities for Improvement</i>	<i>Threats to Success</i>
<ul style="list-style-type: none"> • Scale up of ‘whole-system’ approaches towards heating will allow for the potential in geothermal energy, industrial waste heat and other energy stores to be more efficiently and cost-effectively utilised to heat buildings sustainably. • Stimulation of the private sector, clear messaging and example setting by local authorities will support future Government decision making and rally private sector resources and support for the purposes of building decarbonisation. • Further compartmentalisation of efforts surrounding national decarbonisation could help to ensure more dedicated teams of individuals are working on particular areas, such as building decarbonisation, which in turn should ensure better coordination of the national effort and that collaboration between stakeholders becomes more effective. 	<ul style="list-style-type: none"> • Energy security issues are increasingly likely following the closure of the Groningen natural gas field and the war in Ukraine placing natural gas supplies, and thus any renewable substitutes, under pressure. • Lack of Government support at the local level risks the failure of local plans and initiatives. • Lack of detailed plans and incoherence across the national effort compromises the Government’s capacity to deliver upon commitments. • Poor monitoring capabilities hinders any attempts to quickly reform decarbonisation strategy subsequently slowing down the pace of the Netherlands’ decarbonisation efforts.
<i>Transparency</i>	



Dutch Government plans surrounding building decarbonisation along with any subsequent policies and measures are comprehensively and concisely summarised and presented in full for the public to access.

6. German Government Strategy

6.1. Overview

In 2019 the German Federal Government would pass its ‘Climate Action Programme 2030’ [30] and ‘Energy Efficiency Strategy 2050’ [31] (which incorporates the new ‘National Action Plan on Energy Efficiency’ or NAPE 2.0) reaffirming Germany’s previous commitment to achieving Net-Zero by 2050 and a 55% reduction in national emissions by 2030. Such publications would expand upon Germany’s previous 2016 ‘Climate Action Plan 2050’ [32] and be summarised in its 2019 ‘Integrated National Energy and Climate Plan’ [33]. This summary would later be supplemented by the more recent publication of Germany’s 2020 ‘Long term Renovation Strategy’ (LTRS) [34] and ‘Immediate Climate Action Programme 2022’ [35] where updated ambitions have increased Germany’s 2030 emission reduction target to 65% and brought its Net-Zero target forward to 2045 [35]. Additional details outlined include steps that will be taken over the next several decades to decarbonise Germany’s buildings sector which comprises of approximately 19 million buildings and accounts for 40% of national emissions (when factoring in emissions incurred from providing electricity and facilitating construction) whilst also accounting for 35% of total final energy consumption [31]. Such steps aim to support those previously outlined in the Federal Government’s dedicated 2015 ‘Energy Efficiency Strategy for Buildings’ [36] which continues to remain relevant to Government strategy in 2022.

6.2. Objectives

The following aims and objectives have been summarised from the German Government’s 2019 ‘Integrated National Energy and Climate Plan’ [33], 2015 ‘Energy Efficiency Strategy for Buildings’ [36], 2019 ‘Energy Efficiency Strategy 2050’ [31] and 2016 ‘Climate Action Plan 2050’ [32] although it must be noted that upcoming revisions to current legislation surrounding Germany’s buildings sector will seek to greatly refine and expand upon the objectives summarised below.

Table 20: German Government commitments and target dates surrounding its wider aims and objectives.

<i>Wider Aims</i>	
<i>Commitment</i>	<i>Target Date</i>
Achieving a virtually climate-neutral building stock in which energy demand is considered very low and is covered by renewable energy.	2050
Ensuring total emissions from the buildings sector do not total more than 70-72 million tonnes of CO ₂ per year.	2030
Bringing the planned review of the Building Energy Act forward where significant amendments will take place surrounding standards for new buildings.	2022
Improving the data stock for buildings to incorporate information regarding the current condition of building stock, better classification, modernisation trends, energy usage and the use of renewable energy.	Ongoing to meet other target deadlines.

Furthering research and innovation to ensure the necessary measures are available to meet long term building decarbonisation targets.	Ongoing to meet other target deadlines.
Exploring the use of building lifecycle analysis to support the transition towards a more resource efficient circular economy.	Ongoing to meet other target deadlines.

Table 21: German Government commitments and target dates surrounding energy production and usage.

Energy Production and Usage	
Commitment	Target Dates
Ensuring a share of 24-32% of renewables in the buildings sector is achieved.	2030
Increasing the share of renewables in heating networks to 25% in the short term before increasing it further to 30%.	2025 (short term) 2030 (long term)
Increasing the share of renewables in the heating and cooling sector by 1.3% per year between 2020-2030 to achieve a 20.5% share in the short term before later reaching 27%.	2025 (short term) 2030 (long term)
Ensuring 50% of the heat supply is produced on a climate-neutral basis.	2030
Achieving a reduction in energy consumption from buildings of 66-67% to support the national target of reducing primary energy consumption by 30%.	2030
Ensuring that all newly installed heating systems are powered by at least 65% renewable energy.	2024
Ensuring that all new buildings are built to the KfW 40 energy efficiency standard.	2025
Reducing primary energy demand across the buildings sector by 80%.	2050

Table 22: German Government commitments and target dates surrounding building energy renovations.

Building Energy Renovations	
Commitment	Target dates
Ensuring the regulatory framework is such that any work done to improve the energy efficiency of existing buildings is climate neutral.	2030
Improving energy performance standards for residential and non-residential buildings.	Ongoing to meet other target deadlines
Ensuring all Government buildings meet at least an EH 40 standard initially before mandating a minimum EH 55 standard for all new buildings and renovations.	2022 (EH 40) 2023 (EH 55)
Working towards the EU 'Renovation Wave' target of doubling the refurbishment rate compared to 2020 levels.	2030

6.3. Approach

To ensure the targets outlined above (tables 20-22) are met, the German Government has detailed a multitude of key steps and measures, summarised below (table 23), that can be broadly categorised into four primary areas of focus. For an overview of supporting instruments outlined in Germany's 'Long term Renovation Strategy' [34] (LRTS) see appendix C.

Table 23: Key steps and measures defining the German Federal Government's approach towards building decarbonisation and delivering on its commitments, categorised into four primary areas of focus [33], [34], [36].

<p>Funding Improvements</p>	<ul style="list-style-type: none"> • Funding for the 'Energy consulting for residential buildings' programme has recently been increased from 60% to an 80% subsidy. • The Federal Government's 'CO₂ Building Modernisation Programme' funds energy-related efficiency renovations and the construction of high-efficiency new build residential and non-residential buildings. It previously stood as the most generously funded programme in the field of energy efficiency (with 2.5 billion euros pledged on new commitments in 2020) and yet saw a further 10% increase in funding rates in 2020. • The Federal 'Funding for Efficient Buildings Scheme' (BEG) packages existing investment funding programmes for the buildings sector (including the CO₂ Building Modernisation Programme and Market Incentive Programme) into a single offering, greatly increasing user-friendliness and appeal. A single application will now facilitate funding for efficiency measures and a transition to renewable energies, offering 40% upgrade premiums for more efficient heating systems. The scheme also delivers improved consulting interfaces, increased funding of sustainability requirements and increased funding of digitisation measures aimed at optimising operation and energy consumption. • Carbon pricing introduced in 2021 shifts heating energy levies onto the public budget (appendix B) with CO₂ emissions being charged by increasing amounts (10 euros per tonne CO₂ in 2021 , 35 euros per tonne CO₂ in 2025). This additional revenue will be used in part to reduce electricity costs for the average household.
<p>Building energy renovations</p>	<ul style="list-style-type: none"> • Independent consultations with Verbraucherzentrale Bundesverband are funded by the Federal Government and intend to eliminate bias and obstacles to energy renovations and the increased use of renewables. • Energy consulting for residential buildings, non-residential buildings and SMEs facilitates the full inspection of a property or enterprise by an energy efficiency expert and the formulation of a subsequent energy efficiency report for the property/enterprise owner, detailing potential energy-savings as well as the economics of any relevant renovations. • The 2019 'New Buildings Energy Act' (GEG) creates a single, coordinated set of rules surrounding energy requirements for new and existing buildings as well as for the use of renewable energies for heating and cooling. This act will undergo review in 2022 (brought forward from 2023) to implement measures relating to energy conservation and tighten current rules by improving required efficiency standards and increasing the required share of renewable energy used for heating. • Financial incentives are offered to stimulate the replacement of inefficient heating and hot water circulation pumps with high efficiency pumps, and the optimisation of heating systems through hydraulic balancing. Funding currently covers 30% of net investment costs and serves as a gateway to more comprehensive energy efficiency measures in buildings. • Tax incentives cover 20% of investment costs surrounding individual renovation measures to owner-occupied residential property and can be taken up as an alternative to other funding programmes. • Development of 'Energy-efficient urban redevelopment' will seek to implement comprehensive measures for the energy efficiency of buildings and supply infrastructure at the district level helping to stimulate even greater energy efficiency across the municipal sector. • Government buildings will play an exemplary role in implementing energy efficiency measures and promoting sustainable construction. To this end, new innovative technologies will be incorporated to transition

	<p>Government buildings to be more sustainable and meeting stricter building efficiency standards will be made compulsory (EH 40 minimum from 2022 increased to EH 55 from 2023 for all new buildings and renovations).</p> <ul style="list-style-type: none"> • Increased development of smart technologies/ digitisation (namely smart meters and building information modelling) is identified as a crucial aspect of improving building decarbonisation by helping to improve planning, construction, operation and maintenance of buildings. • Serial renovation work will be supported with additional funding to aid industrial prefabrication of façade and roof elements, and standardised installation of systems technology, including the supply of self-generated electricity. Such support aims to ensure buildings are renovated to a high standard and in as short of a time as possible.
<p><i>Development of renewable energy in the buildings sector</i></p>	<ul style="list-style-type: none"> • National efficiency labels for old heating installations seek to increase the replacement of old inefficient heating technologies whilst providing an incentive for consumers to save energy by replacing old natural gas boilers. • To increase the replacement rate of oil-based heating systems with renewable heating the 'Market Incentive Programme' provides funding for new installations that use renewable energies to generate heating and cooling as well as heat storage facilities and heat networks. • The 'Energy Efficiency Incentive Programme' provides additional funds to the 'Market Incentive Programme' with the aim of supporting the implementation of stationary fuel cell heating systems in new and existing buildings. • Funding in the form of the 'Support programme for heating optimisation' (HZO) seeks to stimulate the development of heat networks (Heating Network System 4.0), heat storage facilities and cross-building investments which involve supplying buildings with heating and cooling from renewable energies. • A 'Centre of Excellence for the Municipal Heat Transition' has been set up to provide information and advice to municipalities concerning municipal heat planning for which the Federal Government is seeking to support with a statutory guidance framework to encourage more widespread adoption. • A not yet approved 'Federal assistance for efficient heat networks' instrument will seek to fund the expansion and decarbonisation of heat networks.
<p><i>Research, innovation and public interaction</i></p>	<ul style="list-style-type: none"> • Further development of the innovative 'Future Building' programme seeks to support climate protection, energy and resource efficiency, affordable construction, quality of design and management of demographic change with 'creating climate friendly and environmentally friendly building methods' being a key research priority. Additional research areas cover climate neutral construction, land conservation, renewable raw materials and building concepts that exclusively use renewable energy sources. • The 'Building the Energy Transition' initiative seeks to bundle together the various research topics surrounding building decarbonisation whilst improving awareness of energy innovations through targeted research communications. • The 7th 'Energy Research Programme' (ERP) establishes so called 'real laboratories' where both innovative technologies and integrated energy concepts surrounding building decarbonisation are to be tested under real

	<p>life market conditions such to improve regulatory frameworks and transform the energy market.</p> <ul style="list-style-type: none"> • The ‘Germany makes it efficient’ campaign will be improved to include more technically specific information that is more closely tailored to target groups. Such efforts support ongoing public communication initiatives that aim to ensure people remain informed and invested in the decarbonisation of their properties. • To improve public trust, significant ongoing measures are in place to ensure new engineers are trained in energy efficiency measures (and existing engineers are retrained) and that dedicated qualifications are in place to deliver quality assurances in both training and renovation work carried out.
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6.4. Critique and Recommendations

In 2022, the Federal Ministry of Economics and Climate Protection would release its assessment of Germany’s current climate action status [37]. The assessments findings as well as conclusions from both the IEA’s [38] and European commission’s [39] 2020 assessments of Germany’s building decarbonisation strategy have been summarised below (table 24).

Table 24: Federal Ministry of Economics and Climate Protection, IEA and European commission critique and recommendations concerning Germany’s building decarbonisation strategy [37],[38],[39].

<i>Critique</i>	
<i>Policy</i>	<ul style="list-style-type: none"> • Efforts to couple energy efficiency strategy with climate strategy have been an effective way to ensure that both energy and climate policies are aligned towards achieving the same goals. • Germany stands as a leader in Europe concerning setting new building standards and offering financial incentives for energy savings. • Germany’s ‘Efficiency First’ strategy is substantiated with detailed plans outlining how such a strategy will be put into practise. • There has been a failure in recent years to adequately adapt legal standards for refurbishment and new construction to technical advancement surrounding building decarbonisation. This has resulted in minimal emission reductions despite the high levels of subsidies that have paid over recent years to fund building renovations. • More work needs to be done to quickly strengthen measures to reduce barriers and market failures that hinder building renovations. • Additional measures and strengthened ambitions are required to transition away from fossil fuels (such as natural gas) for heating, a reality of particular concern in light of the recent outbreak of the Russo-Ukrainian war highlighting Germany’s over reliance on imported natural gas. • Much stronger efforts are needed to implement renewable energies into the buildings sector such to meet 2030 targets.
<i>Delivery</i>	<ul style="list-style-type: none"> • Energy consultation services have been effective in ensuring that households understand the benefits of energy savings and are more inclined to implement renovations. • Particular success has been with regard to Germany’s EPCs for which Germany remains the leading market in Europe fostering both transparency and trust. • The buildings sector has missed its second successive target in 2021 highlighting the fact that without additional immediate actions 2030 targets will be missed. • Final energy consumption is currently on an upward trend and thus requires immediate action to reverse.

	<ul style="list-style-type: none"> • Stagnation in refurbishment rates coupled with the increasing levels of heat demand has resulted in the share of renewables and heat pumps rising only very slowly. • Municipal heat planning is not being adopted to the necessary degree likely due to the lack of standardised methods. • The digitisation of the buildings sector has been hindered due to the roll out of smart meters having been largely insufficient with the average household remaining under no obligation to have one installed.
Outlook	<ul style="list-style-type: none"> • Germany's approach towards building decarbonisation places it amongst the leading nations in Europe with exemplary ambitions and policies surrounding building efficiency standards in particular. • More work needs to be done to reduce Germany's overreliance on natural gas and other fossil fuels for heating and better implement renewable energies into the buildings sector. • Past efforts surrounding building decarbonisation have not been able to achieve associated targets in both 2020 and 2021 highlighting the urgent need for additional measures and reform to ensure 2030 targets are met. • Improving efforts to ensure that the adoption of measures such as smart meters and municipal heat management becomes more widespread in the coming years would go a long way in translating Germany's ambitions into significant action.
Recommendations and Next Steps	
<ol style="list-style-type: none"> 1. Reform and strengthen measures surrounding building energy efficiency to increase the rate and quality of building renovations. *** 2. Expand the roll-out of smart meters to encompass all homes and support the long-term digitisation of the buildings sector to enable flexibility of demand. 3. Take steps to increase the appeal of alternative renewable fuel types to help transition away from fossil fuel boilers to more efficient renewable methods of heating. *** 4. Develop a strong supporting strategy for the use of renewables across sectors, including the buildings sector, to stimulate innovation and competition across renewable fuels such as biomethane, Hydrogen etc. 5. Continue developing regulatory and legal frameworks regarding building decarbonisation to close delivery gaps and ensure that ambitious and comprehensive plans can be translated into real world action. 	

*** Working in line with these recommendations the aforementioned 'Immediate climate action programme for 2022' [35] provides a recent example of some of the immediate steps being taken to address such recommendations.

6.5. Regional Approaches

With such critique in mind, this section shall discuss regional approaches towards the decarbonisation of buildings within Germany where particular initiative and ambition has been observed. Such approaches shall serve as examples to the German Federal Government, demonstrating where current efforts surrounding building decarbonisation have the potential to be improved going forward.

6.5.1. Berlin

In 2018, the Berlin local authority adopted its decarbonisation plans which took the form of the 'Berlin Energy and Climate Protection Programme 2030' [40]. Details within outlined Berlin's commitment to achieve Net-Zero by 2050 and the steps it would take to subsequently reduce building emissions, that accounted for 49% of all emissions across Berlin in 2012, by 84% by 2050 [40]. More recently however, ambitions have been strengthened to achieve Net-Zero by 2045 in line with updated Government targets with further ambitions to phase out coal entirely and facilitate a 70% reduction in emissions by 2030. To this end, Berlin's plans are currently undergoing revision with updated plans set to be released in late 2022. There are still many aspects of Berlin's previous plans however that have seen great success

since 2018 namely its efforts the increase energy sobriety amongst the population and provide targeted funding to accelerate the pace of building renovations.

- **Regional Plans** have been largely successful since 2018 with Berlin beating its previous 40% emission reduction target for 2020, achieving 41.1% reductions in 2019 compared to 1990 levels. Such plans contain approximately 100 measures on climate mitigation and form the basis for multiple funding programs covering heating replacement and other areas [40]. If implemented, these measures will reform Berlin's energy mix to consist entirely of renewables with renewable gases forming a major part of heating resources by 2050. The wide-spread energy-efficient refurbishment of Berlin's growing number of buildings will also be facilitated in a socially acceptable and inclusive way that ensures the city's population are able to contribute to local decarbonisation efforts. For instance, citizens are encouraged to install solar thermal systems in their homes and seek further consultation regarding how the energy efficiency of their homes can be improved further [40]. Energy renovations for Berlin's public buildings in particular are setting the example for building efficiency in line with Government intentions [40].
- **The Efficient Buildings PLUS Programme** seeks to support the energy-efficiency renovation of both residential and non-residential buildings across Berlin whilst facilitating the continued funding from the Berlin Heating Exchange Program that officially ended in 2021. Through the issuing of grants the programme primarily focuses on private building owners and seeks to provide funding that promotes energy-efficient refurbishments thus helping to reduce CO₂ emissions across Berlin's buildings sector in line with the city's goals. The funding programme itself is split into five funding modules covering: Thermal insulation of the building envelope, building-specific renovation roadmaps, exchange and optimization of plant technology, digital systems for optimising energy efficiency and consumption and comprehensive renovation of buildings to achieve an efficiency house level [41]. Such a programme ensures Berlin's citizens are supported every step of the way in making renovations to their homes and ensures that any renovations carried out exploit the significant potential for energy savings unique to each home. Module four in particular helps accelerate the rate at which technologies such as smart meters are adopted thus aiding the wider digitisation of the buildings sector, an area noted by the IEA to be of need of improvement across Germany (table 24) [38].
- **Increasing Sobriety and Participation** has also played an important role in achieving Berlin's building decarbonisation ambitions with Berlin's 'ImpulseE' Programme providing a central platform for the city's citizens to learn more about energy efficiency [40]. More broadly the platform aims to promote the wider climate protection of the city, informing companies, public institutions and private households on what they can do to support the wider decarbonisation of the city. For example, people are encouraged to adapt their daily routines to increase energy efficiency by: Ventilating rooms more thoughtfully to prevent heat from escaping as easily, switching off electronics on standby and purchasing more efficient household appliances [40]. Citizens are also being encouraged to support tenant electricity schemes by looking for ways that their electricity can be produced onsite i.e. by installing solar thermal technologies. By informing and including the population Berlin has been able to exceed its own expectations highlighting the benefits of fostering energy sobriety whilst appealing to and supporting the public to decarbonise their homes wherever possible. National use of such an approach is reminiscent of France (section 4) and could help Germany increase the adoption of voluntary measures such as smart meters and municipal heat planning avoiding the need to make them compulsory in the future.

6.5.2. Munich

Following the declaration of a climate emergency by Munich's city council in 2019, plans were drawn up in which Munich would commit itself to achieving Net-Zero by 2035, ten years earlier than the national 2045 target [42]. Within such plans the city council would outline how it intended decarbonise its 800,000 households (80% of which were built before 1949), industrial firms, streetcars and subways that together consume 7.5 billion kWh of electricity per year on average [42]. A more recent sustainability report published in 2021 [43] would continue to expand upon previous plans, formulating ambitious new targets surrounding expanding renewables and heating in particular, before detailing how such targets will be achieved going forward.

- Regional Plans** within Munich have centred largely on the expansion of renewables and decarbonisation of district heating. For instance, by 2025 Munich intends to cover all electricity demand by renewable power produced within the local region (figure 9) [43]. In 2021, approximately 4.9 billion kWh of green electricity was produced locally, a figure expected to rise to supply up to 90% of total electricity demand by 2022 with plans already in place to expand production further to adapt to rising levels in demand [43]. Furthermore, by 2040 Munich intends to achieve CO₂ neutral coverage of its district heating requirements with plans to do so relying heavily on geothermal solutions [43]. For example, in 2021 Munich operated a total of six geothermal plants (figure 9) with Germany's largest plant, situated locally to Munich, beginning full operation in early 2022 subsequently providing 80,000 Munich citizens with green heating [43]. Additionally, in 2021 successful heat extraction was achieved at Munich's Kirchstockach plant enabling it to provide renewable heating on top of renewable electricity. By 2025 the city will have pledged 200 million euros to expand geothermal energy production alone alongside a further 650 million to expand other methods of renewable energy production and 700 million to modernise existing grid infrastructure [43]. On top of such ambitions Munich is also looking to expand district cooling which can yield 50-70% reductions in electricity consumption compared to individual cooling, incorporating district heating to formulate an efficient, city-wide, whole-system approach to both heating and cooling [43].

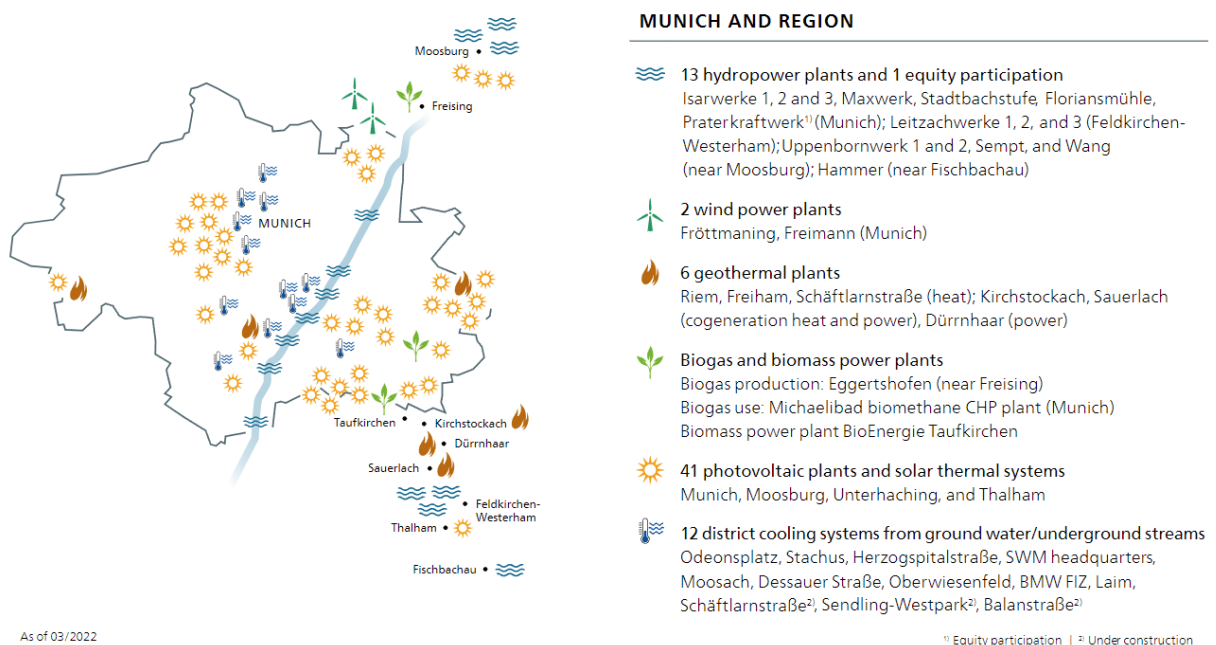


Figure 9: Renewable energy production site types and locations throughout Munich and the surrounding local region [43].


- **Local Opportunities** have provided the city of Munich with great potential to expand upon and fulfil its building decarbonisation targets, subsequently enabling Munich to adopt a leading role with regards to regional transitions to net-zero. It was the Munich local authority however, that was able to identify such opportunities and exploit them to enable the city to begin ambitiously transitioning towards entirely renewable power by 2025 whilst capitalising further on its abundance of geothermal energy to decarbonise its district heating by 2040. Such opportunities are available for regions across Germany with each having its own various unique advantages from which to kickstart decarbonisation efforts. Subsequently the Federal Government must ensure that any national advantages that could possibly support building decarbonisation efforts are being investigated and exploited whilst simultaneously ensuring that regional authorities are both supported and incentivised to take advantage of their own regional opportunities to drive decarbonisation efforts.

6.6. Summary



Table 25: Overall summary of the German Federal Government's strategy to decarbonise its buildings.

German Federal Government Heat and Buildings Strategy	
Strengths	Weaknesses
<ul style="list-style-type: none"> • Germany stands as a European leader with regards to its approach surrounding building decarbonisation with exemplary building efficiency standards and support for building energy renovations. • Germany's plans are often highly detailed and substantiate broader claims to be working under an 'Efficiency First' principle. • Energy consultations have been effective at incentivising homeowners to renovate by increasing public confidence in renovation work and measures. 	<ul style="list-style-type: none"> • Ambitions and efforts to shift away from fossil fuel heating systems and better implement renewables into the energy mix of buildings have been insufficient. • Many current measures remain voluntary and have seen poor levels of adoption. • Increasing trends in energy consumption as well as missed 2020 and 2021 targets highlight an urgent need for increased action and reform of previous plans surrounding building decarbonisation. • Failure to adapt legal standards surrounding building renovations to recent technical advancements has seen renovation rates stagnate whilst doing very little to reduce real world emissions.
Opportunities for Improvement	Threats to Success
<ul style="list-style-type: none"> • More targeted support schemes for areas concerning the digitisation of the buildings sector could go a long way to ensure smart meters and other relevant voluntary measures are adopted. • National strategy could do a lot more to help increase levels of environmental sobriety amongst the population to foster innovation, increased climate action and encourage the adoption of voluntary measures. • Effective identification and exploitation of regional and national opportunities for facilitating building decarbonisation could yield significant benefits enabling the 	<ul style="list-style-type: none"> • Germany's high reliance on natural gas imports has exposed it to considerable risk in 2022 following the outbreak of the Russo-Ukrainian war. Subsequent plans must ensure these risks are mitigated to ensure energy security and the increased rate of transition towards renewable forms of heating. • Stagnation in refurbishment rates has resulted in the roll out of measures such as heat pumps to slow down significantly, jeopardising targets and hindering the wider implementation of building decarbonisation measures.

possible expansion of ambitions or at least ensuring current targets can be met more easily.	<ul style="list-style-type: none"> Reliance on voluntary measures must be supported by additional appropriate policies and measures to incentivise more widespread adoption and prevent the low-levels currently observed across Germany.
Transparency	
 <p data-bbox="204 551 1337 674">German Government plans surrounding building decarbonisation along with any subsequent policies and measures are comprehensively outlined however objectives and measures could be more concisely summarised and recent key publications could be made more accessible to the public.</p>	

7. Italian Government Strategy

7.1. Overview

Previous key climate action publications from Italy include its 2017 ‘National Energy Strategy’ [44] and ‘National Strategy for Sustainable Development’ with both forming a quoted ‘initial starting point’ for Italy’s 2019 ‘Integrated National Energy and Climate Plan’, covering proposed climate action for the period 2021-2030 [45]. Included details outline Italy’s commitment to achieving full decarbonisation by 2050 whilst working to achieve the wider medium term emission reduction targets defined for Italy by the EU. To this end, Italy has also detailed its objectives and approach towards decarbonising its 12.4 million residential buildings (65% of which are over 45 years old) and 1.5 million non-residential buildings which together brought building sector related energy consumption to 45% of total final energy consumption and direct emissions to 17.5% of the national total [46] in 2021. Such efforts are further elaborated on within Italy’s more recent 2021 ‘Strategy for Energy Retrofitting of National Building Stock’ [46].

7.2. Objectives

The following aims and objectives have been summarised from Italy’s 2019 ‘Integrated National Energy and Climate Plan’ [45] and 2021 ‘Strategy for Energy Retrofitting of National Building Stock’ [46].

Table 26: Italian Government commitments and target dates surrounding its wider aims and objectives.

Wider Aims	
Commitment	Target Date
Increasing the energy efficiency of pre-existing buildings and the application of high performing technologies to reduce civil sector emissions by 35 MtCO ₂ eq compared to 2005.	2030
Achieving the complete decarbonisation of the civil sector with the elimination of all associated direct emissions.	2050
Continuing to develop measures to finance technological innovation and research to further improve energy efficiency measures.	Ongoing to meet other target deadlines.
Promoting energy efficiency to help tackle energy poverty and support information and training campaigns aiming to modify behaviours and accelerate building energy renovations.	Ongoing to meet other target deadlines

Table 27: Italian Government commitments and target dates surrounding building energy renovations.

Building Energy Renovations

Commitment	Target Date
Facilitating full renovation of the existing building stock to meet updated efficiency standards compatible with 2050 targets.	2050
Accelerating annual VDRR (virtual deep renovation rate ^{***}) to approximately 0.7-0.8% for the residential sector.	2020-2030
Accelerating annual VDRR (virtual deep renovation rate ^{***}) to approximately 4% for the tertiary sector (2.9% for the non-residential sector when excluding hospitals).	2020-2030
Ensuring 3% of the total floor area within central public administration buildings are renovated annually enabling 3.2 million m ² of floor area to be renovated between 2021-2030.	2021-2030

^{***} Virtual deep renovation rate assumes that the renovations being carried out are extensive and does not include minor renovations.

Table 28: Italian Government commitments and target dates surrounding energy production and usage.

Energy Production and Usage	
Commitment	Target Date
Increasing the share of renewables across the heating sector from 18.9% (2016) to 33.9% in line with wider national targets aiming to increase the share of renewables to account for 30% of gross final energy consumption.	2030
Reducing the gross final energy consumption for heating from 55,796 Ktoe (2016) to approximately 44,000 Ktoe in line with wider national targets to reduce primary energy consumption by 43% and final energy consumption by 39.7%.	2030
Enabling final energy savings of 0.33 Mtoe/year for the residential sector.	2021-2030
Enabling final energy savings of 0.24 Mtoe/year of for the tertiary sector.	2021-2030
Encouraging the replacement of domestic wood-fired systems with more efficient, low-emission systems that meet new environmental standards.	Ongoing to meet other target deadlines.
Devoting increased attention to high efficiency heat pumps to increase its share of the thermal renewables mix.	Ongoing to meet other target deadlines.
Expanding the use of efficient district heating and cooling by exploiting various opportunities such as the reduced demand for energy recovery from waste heat and limited use of biomass.	Ongoing to meet other target deadlines.

7.3. Approach

To achieve the targets outlined above (tables 26-28) Italy has outlined a series of key policies and measures, summarised below (table 29), that have been categorised into five primary areas of focus. It is important to note that it is stated within Italy's NECP [45] that the vast majority of measures intended to promote the use of thermal renewable energy sources (through technologies such as heat pumps) are often integrated with those for energy efficiency. Subsequently, stated measures concerning heat pumps and heat networks directly are uncommon.

Table 29: Stated areas of focus and key steps and measures defining the Italian Government's approach towards building decarbonisation and delivering on its commitments [45],[46].

'Residential buildings'	<ul style="list-style-type: none"> • Tax reductions for energy-efficient renovations and restoration of existing buildings (also known as the 'Ecobonus') aims to support an upward trend in deep building renovation rates and the increased energy performance of residential buildings.
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	<ul style="list-style-type: none"> • The 'Superbonus' supplements the 'Ecobonus' by providing 110% remuneration of expenses associated with certain energy-efficient renovations with support being offered, albeit whilst gradually decreasing in size, until late 2025. • Implementation of deep renovation measures will further be incentivised through increased volume limits for buildings, reduction of property transfer taxes and reduced municipal taxes. • Integration of the many tax deduction incentives that are available into a single offering through reform of the current regulatory framework seeks to streamline current processes and optimise the effectiveness of such measures. • The 'Conto Termico' (Thermal Energy Account) is a non-repayable capital contribution and acts as an incentive for promoting the production of renewable thermal energy whilst permitting access by public sector bodies to carry out energy-efficient building works and installations. Such works include: Installation of heat pumps, biomass heating generators, solar thermal installations and a wider use of geothermal/hydrothermal energy with up to 65% of associated costs covered by the grant. • Planning and consultancy tools will be developed for Italian citizens to make the process of improving the performance of one's home more accessible and transparent. • Schemes such as the 'Ecobonus', 'Superbonus', 'Conto Termico' and 'National Energy Efficiency Fund' are available for public housing to help tackle energy poverty on top of additional electricity and gas bonuses. • Regional approaches towards tackling energy poverty have been identified by the Italian Government where opportunities for national scaleup could be possible.
<p><i>'Non-residential buildings'</i></p>	<ul style="list-style-type: none"> • The 'Conto Termico' is becoming increasingly accessible for public bodies and more focused on enabling the energy efficient retrofitting of non-residential buildings which could see 100% of all renovation costs covered by the grant. • The 'Energy Renovation Programme for the Central Public Administration' seeks to accomplish the annual 3% renovation of floor area within central government buildings as previously mentioned (table 27). By 2021, the scheme had facilitated 195 energy retrofitting projects worth a combined 270 million euros with future plans in place to speed up implementation. • Minimum environmental criteria is in place requiring an energy audit to be performed, for buildings undergoing maintenance, in order to categorise a building's energy performance and outline subsequent measures that can reduce the building's energy requirements. Furthermore, new buildings must obtain their energy from renewable sources or from alternative high efficiency systems. • The 'National Efficiency Fund' and 'Kyoto Fund' support the renovation of public schools. • 6.1 billion euros will be made available between 2020-2034 to be spent specifically on public buildings and infrastructure with funds covering work surrounding maintenance, safety and energy efficiency measures. A further 400 million euros will be issued between 2025-2034, as part of an additional fund, to supplement these measures. • 50,000-250,000 euros will be made available through the 'Development and Cohesion Fund' to municipalities, depending on

	<p>population size, to help them make their buildings and territory safe and efficient (through possible expansion of district heating where appropriate).</p> <ul style="list-style-type: none"> • White certificates certify that a reduction of end-use energy consumption has been attained as a result of interventions and projects to increase energy efficiency and exist as tradable assets.
<p><i>‘Smart, interconnected buildings and energy communities’</i></p>	<ul style="list-style-type: none"> • Newly constructed non-residential buildings as well as those subject to major renovations must have a minimum level of automation of class B (UNI EN 15232 standard) achieved through the obligatory installation of smart systems. • Newly constructed buildings or buildings subject to major renovation since 2018 are required to ensure that at least 50% of demand for heating, cooling and hot water is covered by renewable thermal energy. • Existing buildings can seek support through the ‘Conto Termico’ which enables the installation of building automation and control measures (BAC). • The existing ‘Ecobonus’ scheme provides support for costs incurred through the purchase and installation of devices which enable the remote control of heating, hot water production or air conditioning. • Self-consumption and energy communities seek to ensure that citizens become beneficiaries of the energy transition and not just its financiers. The creation of such communities is still in its early phases with regional approaches taking the lead in this area. Such communities involve ‘Renewable self-consumers’ which consist of individuals or groups who produce and store electricity for their own consumption. • It is recognised that building renovation incentives must be coupled with effective information campaigns targeting increased awareness of one’s own individual energy consumption and the cost savings associated with renovations and behavioural changes.
<p><i>‘Skills and training’</i></p>	<ul style="list-style-type: none"> • A regulatory framework for skills and training surrounding energy building renovations has been outlined detailing key required competencies, measures to grow the labour market and minimum service standards. • The Italian ‘BUILD UP Skills roadmap to 2020’ has facilitated: training for trainers, on the job training and certification of competences and has been followed up by the more recent ‘Horizon 2020’ programme. • The ‘BRICKS’ project (funded by the ‘BUILD UP Skills roadmap’) has developed qualifications for a multitude of professional roles seeking to support building refurbishment with increased competencies, knowledge and skills. • The ‘TOWN’ project (also funded by the ‘BUILD UP Skills roadmap’) supports the development of a training qualification workforce. • The ‘REEHUB’ project assesses the comfort and air quality for schools subject to energy renovation. Work carried out in this project includes developing audit methodology and capacity building actions for energy efficiency in buildings. • Summer schools have been set up which educate professionals about the latest technologies and specific aspects relating to energy efficiency within the built-up environment as well as water recovery, comfort, ventilation and bio-materials.
<p><i>‘Financial tools’</i></p>	<ul style="list-style-type: none"> • The Italian Banking Association have signed a ‘Joint Declaration for the valorisation of buildings’ to promote initiatives aimed at improving

	<p>energy management, support the development of new financial products for green development and develop information and training initiatives to advertise a culture of adaptation and climate mitigation.</p> <ul style="list-style-type: none"> • A series of additional financial tools have been implemented to tackle the wide array of barriers to building decarbonisation. For a summary of such measures see appendix D. • Going forward it is identified that more must be done to develop a standardised method for assessing financial risk particularly with regard to green mortgages. This may be done through of a combination of measures targeting the use of technical standards as a tool to reduce risk, the development of systems to standardise processes and the creation of a national database to support risk assessments.
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7.4. Critique and Recommendations

In January 2022, BPIE released their assessment of ambition levels for new building standards across the EU covering Italy in the process [47]. Their conclusions as well as those from the Climate Transparency's [48] and the European Commission's [49] evaluations of Italy's building decarbonisation strategy have been summarised below (table 30).

Table 30: BPIE, Climate Transparency and European commission critique and recommendations concerning Italy's building decarbonisation strategy [47], [48], [49].

Critique	
Policy	<ul style="list-style-type: none"> • Sufficient detail is provided concerning actions and targets for renovation of the existing building stock. • Standards for new residential buildings are much more ambitious than for non-residential buildings which remain amongst the least ambitious in Europe. • Standards surrounding renewable energies for heating are amongst the best in Europe yet still lower than required to meet long-term targets. • More broadly, ambitions for the residential sector are more ambitious than for many other areas relating to building decarbonisation. • Italy has no official policy in place regarding the explicit phasing out of fossil fuels across its buildings sector. • Plans do not detail any specific targets surrounding tackling energy poverty. • There is no discussion of how measures primarily targeted at energy efficiency will support the increased use of renewable heating (as stated to be the case in Italy's NECP).
Delivery	<ul style="list-style-type: none"> • Italy is an outlier with regard to its low levels of new construction where rates of new building activity are amongst the lowest in Europe. Such low levels of newly constructed 'net-zero emission buildings' (NZEBS) makes reliable analysis of energy performance and the uptake of new standards more challenging. • Schemes such as the 'Superbonus' stand as strong measures to help accelerate the rate of deep retrofits of existing buildings where decarbonisation efforts are currently largely centred. • Policy makers have a high degree of confidence that the market will be able to deliver NZEBs when supported by increased training initiatives and increased construction activity however this remains to be seen. • Italy has managed to decrease building related per-capita emissions by 15% between (2015-2020), five times faster than the G20 average. • Italy has been largely successful at meeting its short-term targets concerning emission reductions, expanding the share of renewables and reducing energy consumption.

	<ul style="list-style-type: none"> Proactive measures to combine existing financial incentives into simpler and more accessible offerings are a welcome addition to current financial support, targeting building decarbonisation, and will help to ensure such support is as effective as possible.
Outlook	<ul style="list-style-type: none"> Italy has seen significant gains with regard to energy efficiency, emission reductions and increased share of renewables enabling many short-term targets to be met. Italy's plans to decarbonise its buildings sector remain uneven in their levels of ambition across areas including the residential sector, non-residential sector, implementation of renewable heating and financial support. Gaps exist regarding Italy's intentions to tackle energy poverty and phase out fossil fuel use in existing homes. Levels of new construction have been extremely low, hindering the ability to assess the effectiveness of new initiatives and policies surrounding new NZEBs.
Recommendations and Next Steps	
<ol style="list-style-type: none"> Develop a fossil fuel phase out plan and restrict the use of fossil fuels within new buildings by 2025. Increase the required share of renewable energy contributing towards a building's primary energy consumption to 100% coverage for NZEBs by 2025 and increase clarity on how current efficiency measures will help facilitate the increased use of renewables for heating. Ensure market needs concerning the training of professionals and the installation of energy efficient technologies are responded to to support the current market-based approach towards transitioning to NZEBs. Match levels of ambition for non-residential buildings and other areas with those for residential buildings and formulate concrete targets surrounding tackling energy poverty to ensure that building decarbonisation efforts encompass the entire civil sector. Expand NZEB standards to incorporate limits on both operational and embodied carbon related emissions and tighten obligations on carbon monitoring for new buildings. 	

7.5. Regional Approaches

This section shall discuss several regional approaches within Italy where particular enthusiasm and initiative has been shown towards both building and wider decarbonisation. Such approaches shall once again provide Italy with opportunities to improve its national efforts towards building decarbonisation and better deliver on its climate commitments.

7.5.1. Milan

On October 4th 2019 Milan's Municipal council would approve guidelines for the formulation of its 'Air and Climate Plan' [50], or PAC, which would later be adopted in January of 2021 to be used as a tool to protect both health and the environment by reducing air pollution and responding to the climate emergency. The plan would outline Milan's wider environmental ambitions which would include Milan's commitment to reduce CO₂ emissions by 45% by 2030 and achieve net-zero by 2050 [50]. To this end, Milan has begun implementing many of its building decarbonisation projects including the construction of Italy's first zero-carbon social housing project [51], participation in the global 'Reinventing Cities Project' and promotion of citizen sponsored decarbonisation initiatives [52]. Such efforts have ensured Milan is filling its role as a key member of the C40 network of globally influential cities committed to fighting climate change.

- Regional Plans** surrounding building decarbonisation within Milan have sought to stimulate processes targeting the replenishment of the existing building stock and networks, improving construction quality, urban planning and the quality of life for citizens. In addition to this, plans have aimed to promote the replacement of fossil fuels with renewables for heating on top of improved home air quality and strengthened citizen awareness of their impact on regional emissions [50]. The implementation of the 'Air and Climate Plan' has

also been highly influenced by Milan's citizens themselves, following the launching of a 'process of public consultation and listening to citizens', in which consultations are held involving citizens, stakeholders, civil organisations and professionals. These consultations are facilitated through a combination of thematic workshops, town hall meetings and a 'Citizens' Table' in which randomly selected citizens are able to discuss their thoughts on Milan's current climate plans [50]. Milan has also been particularly transparent with its efforts, publishing all relevant documents for public access and enabling citizens to monitor and discuss plans in their entirety. This approach has made the citizens of Milan an integral part of its decarbonisation strategy, increasing sobriety and capitalising on the cities sense of community to inform, plan and drive change forward.

- **Zero-Carbon Social Housing** within Milan stands as Italy's first zero-carbon housing project [51], aiming to construct housing districts that will use energy for heating and cooling from renewable sources, 100% reused water and possess green roofs. The surrounding area will also aim to be 60% green spaces and be designed to incorporate green mobility and keep the local air clean [51]. The houses themselves will be designed as NZEBs and be constructed from materials that will allow them to be disassembled and 100% recycled in the future. Innovative new district heating systems, which incorporate wastewater heat recovery, will also be developed with the hopes of making social housing fully carbon neutral over the next 30 years [51]. Such plans showcase a promising blueprint for what sustainable housing districts should look like by 2050 in which housing districts are able to offer affordable, sustainable, climate neutral housing with improved air quality whilst fostering a circular economy. As such close attention should be given to Milan's progress over the coming years to identify which best practises can be scaled up to a national level and support the increased construction rate of NZEBs and zero-carbon districts across Italy, an area identified by BPIE as being in need of improvement (table 30) [47].
- **International Collaboration and Example Setting** have been key traits of Milan's climate mitigation efforts with Milan, for example, having joined the 'Reinventing Cities' initiative for several years now. 'Reinventing Cities' promotes the sharing of knowledge and challenges its participants to present proposals for the redevelopment of abandoned or underused sites to tackle ten primary challenges. With regard to building decarbonisation, challenges include improving energy efficiency and low emission energy, making the management of building materials more sustainable and fostering innovation regarding urban architecture and design [52]. This concept of globally influential cities working independently to propose climate projects has been scaled down to the local level in Milan with citizens and organisations being offered the opportunity to propose their own plans that contribute towards the green transition of the city. Such a scheme enables individual citizens, universities, schools, companies, associations and all manner of other public and private entities to support local green projects being carried out throughout Milan as well as being able propose and personally carry out their own green projects pending the approval of the municipal council [52]. As such, further participation in international collaborations concerning areas relating to building decarbonisation stands to benefit Italy greatly by not only allowing it to set international examples of how to decarbonise (as Milan has) but also enabling it to learn from other world leading countries and cities about what measures and strategies towards building decarbonisation could be beneficial in Italy. Further international collaboration could also, as has been the case in Milan, foster greater local participation in climate projects thus yielding an increased capacity to implement building decarbonisation measures on the ground.

7.5.2. Venice

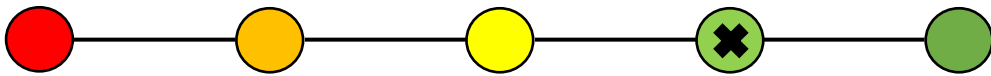
On the 30th April 2020 the city council of Venice approved its accession to the 'Covenant of Mayors for Climate and Energy', the primary global initiative encouraging local authorities to begin implementing measures to tackle climate change, having first joined in 2011 [53]. Such a step commits the city of Venice to drafting plans for its first 'Sustainable Energy and Climate Action Plan' (SECAP) in which its strategy for achieving a required 40% minimum reduction in citywide emissions by 2030 will be outlined. Furthermore, Venice's accession commits the local authority to submitting progress reports on its climate action over the coming years and sharing its results and experiences with other regional authorities across the EU through direct collaboration and knowledge sharing [53]. These commitments aim to support Venice's stated ambitions of becoming climate-neutral by 2050 whilst becoming increasingly resilient in the process, ensuring the city is able to adapt to a changing climate and work towards mitigating the worsening effects of climate change [54].

- **Regional Plans** have seen the city of Venice previously adopt its 2012 'Sustainable Energy Action Plan', or SEAP, produced as part of the aforementioned 'Covenant of Mayors for Climate and Energy' initiative with such plans enabling Venice to reduce its overall emissions by 20% compared to 2005 levels [53]. Additionally, in 2014 the city council would outline its approach towards regional decarbonisation through 'Venice's Climate Future' [55], setting a basis for future climate action pending the release of the city's new SECAP due in late 2022. Detailed within includes ambitions to reduce the level of fossil fuel consumption within buildings through, in part, a transition towards becoming a 'smart city' in which increased digitisation is embraced to enable optimal management of energy supply and demand. With regards to becoming more resilient, Venice also promotes a transition towards a more circular economy and a greater level of symbiosis between its urban environment and its waterways, implementing subsequent good practises which ultimately led to Venice being identified as a 'model city' by the UN 'Making Cities Resilient' campaign [55]. Previous decarbonisation efforts thus lay a strong foundation for the regions upcoming 2022 SECAP in which Venice will seek to provide details concerning its most recent plans to decarbonise its buildings.
- **Transparency** has remained an integral part of Venice's iterative efforts towards decarbonisation in which, much like Milan, the population is consulted to help inform inclusive plans that a majority can agree on. Continued openness has steered Venice to joining the C40, continuing its membership as part of the 'Covenant of Mayors for Climate and Energy' and receiving a mention as part of Cities 100 [51] with continued long-term collaboration and knowledge sharing placing Venice as one of Italy's leading cities with regard to its decarbonisation efforts. Such transparency also means Venice will be held to account for not fulfilling its many climate obligations effectively tying the cities hand for the better, compelling it to make colossal leaps forward to achieve its climate targets. As such, at the national level keeping the population informed on Government efforts and remaining as transparent as possible with regard to successes and failures will encourage feedback from the population, public intuitions and professionals which should subsequently support reform and productively inform future strategy not least for building decarbonisation.

7.6. Summary



Table 31: Overall summary of the Italian Government's strategy to decarbonise its buildings

Italian Government Heat and Buildings Strategy	
Strengths	Weaknesses
<ul style="list-style-type: none"> Plans surrounding the decarbonisation of the residential sector are sufficiently ambitious and are accompanied by strong support schemes. Delivery of measures has been largely successful with many short-term objectives for the early 2020's reached and medium-term targets on track to be achieved. Building standards surrounding renewable heating are amongst the best in Europe. Relatively higher levels of bottom-up consultation have allowed Italy to work with and learn from regional authorities to inform and develop national strategy. 	<ul style="list-style-type: none"> Ambitions are not consistent across different areas of the buildings sector resulting in an uneven approach towards building decarbonisation. Policy gaps are missing surrounding key areas such as tackling fuel poverty and phasing out fossil fuel use within buildings. Levels of new building construction are amongst the lowest in Europe making the monitoring and assessment of new building measures/standards difficult.
Opportunities for Improvement	Threats to Success
<ul style="list-style-type: none"> Lessons can be learned from Milan's attempt to construct Italy's first zero-carbon social housing district with such efforts providing a blueprint of what such a district should deliver, involve and cost. Increased levels of international collaboration stand to benefit Italy's building decarbonisation strategy by enabling it to share knowledge, stimulate further investment in its building decarbonisation projects and learn from its collaborative partners about new ways to improve decarbonisation efforts. Improving levels of transparency and better informing the population about the current plans and state of building decarbonisation efforts will help to utilise the collective intelligence of the population to inform future strategy and further stimulate local climate action. 	<ul style="list-style-type: none"> Reliance on the market to expand the construction of NZEBs must be supported and closely monitored to ensure the current low levels of new construction are increased. Failure to unify ambitions across the buildings sector risks broader long-term targets for the sector not being met. Details surrounding how energy efficiency measures will support the adoption of renewable heating need to be elaborated on further to support delivery efforts and enable more effective monitoring of the effectiveness of such measures for this purpose.
Transparency	
	
<p>Italian Government plans surrounding building decarbonisation along with any subsequent policies and measures are comprehensively outlined in full for the public to access however objectives and other information could be more concisely summarised.</p>	

8. Swedish Government Strategy

8.1. Overview

In 2017 the Swedish Government would adopt 'The Swedish Climate Policy Framework' [56] laying the foundation for the release of 'The Swedish Climate Act' [57] in 2018, committing the Government to releasing annual climate reports as well as updated climate action plans every four years. The new framework would also lead to updated climate objectives and the formation of Sweden's Climate Policy

Council, who's responsibility it is to annually evaluate Government policy alignment with climate goals. Updated objectives would include Sweden's commitment to becoming climate neutral by 2045 (85% emission reduction accompanied by measures to offset the remaining 15%) with supplementary targets encompassing the decarbonisation of the country's approximately 8 million buildings which accounted for 39% of final energy consumption in 2017 [58]. Subsequently more recent plans would be released in the form of Sweden's 2020 'Integrated National Energy and Climate Plan' [59], 2020 'Third National Strategy for Energy Efficient Renovation' [58] and 2020 'Long Term Strategy for Reducing Greenhouse Gas Emissions' [60] where detailed plans and measures aimed at decarbonising Sweden's building sector have been presented.

It should be noted however, that following on from a long history of improving building efficiency (largely due to Sweden's cold climate) the Swedish Government considers the potential to reduce greenhouse gas emissions through increased building efficiency to be much smaller than in the countries previously explored. Furthermore, the share of fossil fuels used for heating and electricity production is also regarded as relatively small and as such improvements in such areas are expected to only have a minor impact on reducing overall direct emissions [61]. This reality is reflected across Sweden's recent decarbonisation efforts and ambitions with other areas such as transport taking a clear priority over building decarbonisation.

8.2. Objectives

Unlike many of the countries previously covered, Sweden generally does not outline national sector specific targets (with the notable exception of transport) with recent climate publications setting no objectives relating specifically to areas including climate adaptation, electricity interconnectivity, funding for research and innovation and indeed building decarbonisation. As such, objectives for beyond 2020 concerning areas such as renovation rates, building standards, renewable heating and other related areas are not present within Sweden's current building decarbonisation strategy being instead replaced with much broader targets centred around emission reductions, renewable electricity generation and energy efficiency. This is not to say however that efforts to decarbonise buildings within Sweden are non-existent (as demonstrated in section 8.3) with the intention being that when working towards achieving the defined overarching targets decarbonisation of the buildings sector will be necessarily achieved along the way, guided by various local short-term goals. Therefore, the primary aims of Sweden's wider climate action remain the current driving force behind building decarbonisation efforts and have thus been summarised below (table 32).

Table 32: Wider commitments of Sweden's climate action driving building decarbonisation efforts [58], [59].

Wider Targets Driving Building Decarbonisation	
Commitment	Target Date
Reducing net greenhouse gas emissions to zero before achieving negative emissions enabling Sweden to become the first fossil-free welfare country in the world.	2045
Facilitating a 63%, 75% and then 85% reduction in net greenhouse gas emissions from sectors outside the EU ETS (ESR sectors) compared to levels in 1990.	2030, 2040 and 2045 respectively
Ensuring 100% of all electricity generation comes from renewable sources.	2040
Ensuring energy consumption becomes at least 50% more efficient compared to 2005, a target also expressed in terms of primary energy supplied with respect to real GDP.	2030
Enabling 50% of final energy consumption to be covered by renewable sources (No target defined for 2030 however projections suggest a 65% share can be achieved).	2020

<p>Making sure through measures targeting spatial planning, the housing market, construction and surveying that all citizens will have a healthy living space which promotes the long-term sustainable management of natural resources and energy.</p>	<p>Ongoing to meet other target deadlines.</p>
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8.3. Approach

To ensure the targets outlined above (tables 32) are met, the Swedish Government has detailed a multitude of key steps and measures, summarised below (table 33), that can be broadly categorised into four primary areas of focus. Such measures have been selected based on the four main principles guiding Swedish energy efficiency policy which have also been outlined below (table 33).

Table 33: Guiding principles and key steps and measures defining the Swedish Government's approach towards building decarbonisation and delivering on its commitments, categorised into four primary areas of focus [58],[59],[62].

<p>Wider collaborations and support schemes</p>	<ul style="list-style-type: none"> • The 'National Regional Fund Programme' supports the shift towards a low-carbon economy across all sectors including the buildings sector, promoting energy efficiency and the use of renewable energy as well as research, innovation and the application of low-carbon technologies. Associated initiatives include: energy efficiency incentives, development of technologies and innovation, energy mapping and energy coaches. • Green leases promote cooperation between property owners and tenants and knowledge sharing to identify renovation opportunities that would be profitable to carry out and result in the improved energy efficiency of the property. • Energy and carbon taxation taxes fossil fuels such as heating oil, petrol diesel, coal and natural gas based on their relative climate impact (appendix B) with taxation rates being revised annually. Such taxes intend to incentivise decarbonisation and yield energy savings across the economy with annual savings for the housing and services sector expected to total 11.7 TWh/year in 2030. • The 'Offentliga Fastigheter Collaboration Fund' exists between the Swedish Association of Local Authorities and Regions and three state property managers with a focus to help reform public lighting, stimulate renovations involving energy efficiency measures, promote energy efficient schools and foster low-energy construction. • Kommuninvest is a non-profit credit institution specialising in financing municipal housing companies, schools and hospitals offering products such as green loans and other specialised products to fund building decarbonisation initiatives. • 'Smart City Sweden' exists as a platform for smart solutions in sustainable cities to be demonstrated whilst seeking to unify regional initiatives for sustainable urban development.
<p>Building energy renovations</p>	<ul style="list-style-type: none"> • The 'Planning and Building Act' sets requirements for both new buildings and alterations to existing buildings covering design, accessibility, usability, fire protection, hygiene, health, environment, water, waste, noise and energy management. The act limits primary energy consumption to 90 kWh/m² for small buildings, 85 kWh/m² for multi-dwelling buildings and 80 kWh/m² for non-residential buildings. • 20% of costs for energy efficiency renovations have been previously refunded to tenants over a seven-year period with further support going to landlords provided renovations improve energy efficiency by at least 20%. Since 2019 however, this scheme has been phasing out.

	<ul style="list-style-type: none"> • Tax deductions for renovations, conversions and extensions applying to associated labour costs are offered to provide property owners with an incentive to carry out energy efficiency renovations. The tax reduction was reduced from 50% to 30 % in 2016 bringing the maximum support to SEK 50,000 per person per year. • Use of the 'Rekorderlig Renovering' method intends to identify cost-effective measures which are able to halve the energy consumption of buildings with preliminary efforts able to achieve this in 70% of cases. The method also provides property owners with a systematic overview of the energy efficiency needs of individual buildings, providing a basis for future renovation decisions. • The Government intends to offer a subsidy to property owners for energy efficient renovations with funding amounting SEK 955 million in 2021, SEK 2.4 billion in 2022 and SEK 1 billion in 2023. The wider aim of the scheme is to improve the profitability of energy efficiency measures. • Numerous European provisions targeting energy efficiency have been adopted in Sweden including the 'Energy Labelling Regulation', 'Ecodesign Directive', 'Energy Efficiency Directive' and the 'Energy Performance of Buildings Directive'. • Steps are being taken to investigate the feasibility of implementing a white certificate system.
<p><i>Development of renewable energy in the buildings sector</i></p>	<ul style="list-style-type: none"> • Technology procurement is being used to stimulate the market's transition towards new, more efficient technologies covering products, systems and processes with such an approach being used in areas such as heating, cooling, ventilation and lighting across the building stock. • New laws require municipalities to establish updated plans for the supply, distribution and use of energy with additional requirements for environmental assessments to be conducted if such plans are expected to significantly impact the environment. • Between 2016-2020 support was provided for individuals and property owners who installed renewable electricity generation and storage systems with grants covering up to 60% of eligible costs up to a maximum grant of SEK 50,000. In 2021 however, this system was replaced with 15-50% tax deductions for green investments such as the installation of solar cells, charging stations etc with tax reductions covering the costs of both labour and material. • Electricity certificates provide extra profit for producers of renewable electricity thus incentivising electricity producers to increase the share of renewables in their overall production. Rapid expansion of renewables more recently however has made such certificates increasingly redundant and thus the system will be phased out fully by 2035.
<p><i>Research, innovation and public interaction</i></p>	<ul style="list-style-type: none"> • The 'National Renovation Centre' (NRC) works with business and academic institutions to expand and distribute knowledge to professionals in the building industry, helping them to carry out renovation work more efficiently to provide more environmentally, economically and socially sustainable buildings with improved levels of performance. • The NRC has released its 'renoveringsinfo.se' website where opinion pieces, news, renovation examples, research and information on specific renovation measures are outlined for free for the public to access.

	<ul style="list-style-type: none"> • The 'Sustainable Building Information Centre' promotes energy efficient renovation and building practises which use sustainable materials and have a minimum impact on the environment. To this end, information is provided on their website covering research, results and experience and is targeted at all relevant groups including professionals, owners, housing associations etc. • The 'Swedish Energy Agency' have developed a series of web-based tools to distribute information regarding energy consumption and efficiency to target groups. Tools include the Energikalkylen, which provides households with information about energy efficiency, and Energilyftet, which trains architects, engineers, customers, technicians, installers, site managers and installers with the aim of educating them in how to support low energy consumption in buildings. • Financial support is offered to municipalities to allow them to provide more comprehensive energy and climate advisory services advising citizens on support schemes for home renovations and what efficiency measures are available. • The 'National Building Specific Information' programme (NBI) studies trends in energy performance, efficiency and renovation of apartment buildings to assess the progress of building decarbonisation efforts across the public building stock. • 'Viable Cities' is the largest strategic innovation programme for smart and sustainable cities ever carried out in Sweden, bringing together over 50 stakeholders from a wide array of specialities with a budget of SEK 1 billion covering the 12-year initiative from 2018-2029. • 'Smart Built Environment' was launched in 2016 and over 12 years aims to establish the right conditions for international competitiveness and sustainable solutions to tackle urban and building societal challenges.
Quoted Guiding Principles [59]	
<ul style="list-style-type: none"> • 'Policies should be general and not linked to specific technologies' • 'Prices must give the right (or required) information' • 'Search costs are reduced because information is produced and distributed' • 'Barriers can be removed, for example by adjusting existing regulations' 	

8.4. Critique and Recommendations

In line with 'The Swedish Climate Policy Framework' [56] the Swedish Climate Policy Council has released its 2022 assessment of Government climate action [61] where its views on recent building decarbonisation efforts have been detailed. The council's conclusions as well as those from the IEA's earlier 2019 assessment on Swedish energy policy [63] have been summarised below (table 34).

Table 34: Swedish Climate Policy Council and IEA critique and recommendations concerning Sweden's building decarbonisation strategy [61], [63].

Critique	
Policy	<ul style="list-style-type: none"> • Swedish energy efficiency policy is a mature area however it has been largely overlooked in recent years with EU ambitions exceeding Sweden's own and energy efficiency not presenting itself as a major theme in many of Sweden's recent climate publications. The result of this has been that energy efficiency across the Swedish economy has progressed much slower than across the rest of the EU in recent years. • Policies for resource efficiency and the circular economy are underdeveloped with no regulatory responsibility, a lack of cohesion and a lack of clear priorities amongst stakeholders.

	<ul style="list-style-type: none"> • Sweden lacks political targets for decarbonising many specific areas including those relating to building decarbonisation such as the aforementioned efficient use of materials. • Current policies surrounding energy efficiency do not do enough to meet wider 2030 efficiency targets. • Building codes are not currently tailored to the different types of non-residential buildings whose energy consumption can vary dramatically.
<p>Delivery</p>	<ul style="list-style-type: none"> • Biomass and waste have been used effectively in the past to decarbonise Sweden's district heating with energy and carbon taxation being the main driver of this transition. • Sweden's 2020 target for a 40% emission reduction compared to 1990 has been achieved. • Government communications are not transparent enough to reliably determine the current state of climate action across Sweden, making assessing the likelihood of Sweden achieving its targets or how effectively efforts have affected emissions across various sectors difficult. • Increased support for building renovations is yet to be fully implemented. • The enforcement of building energy efficiency requirements needs increased attention to ensure support schemes are effective at facilitating an increase in energy efficiency. • Uptake of educational tools to train individuals in energy efficiency measures amongst other areas relating to building decarbonisation has been insufficient, highlighting the need to do more to ensure Sweden has access to the skills it needs to facilitate its climate transition.
<p>Outlook</p>	<ul style="list-style-type: none"> • Overall, Sweden's historic building decarbonisation efforts have been largely successful, resulting in the sector being relatively efficient and renewable compared to other areas such as transport. This has resulted in the sector being largely neglected in recent years however, with decarbonisation plans only encompassing buildings within a wider context and policies often remaining insufficient to achieve national targets. • In 2022, specific targets and measures aimed at building decarbonisation are uncommon and those that do exist often require updating. • New measures and support are needed to ensure that efforts regarding building standards, renovation support schemes and the supply of new skills are updated to overcome newly identified challenges and enable Sweden to catch up to the rest of the EU with regard to wider energy efficiency and building decarbonisation efforts.
<p>Recommendations and Next Steps</p>	
<ol style="list-style-type: none"> 1. Ensure the enforcement of building efficiency standards is improved to support the effectiveness of new and existing renovation measures and support schemes. 2. Consider redefining building standards for different types of non-residential buildings to ensure that the standards set are tailored and appropriate. 3. Make sure policies and targets for energy efficiency become more stringent to ensure wider 2030 targets can be achieved and that Sweden can catch up with the rest of the EU with regard to making its economy more energy efficient. 4. Increase the levels of monitoring and transparency, with regard to climate action, to enable the individual contributions of sectors towards achieving wider energy efficiency targets to be tracked and more effectively improved if necessary. 5. Develop a dialogue with educational institutions concerning how to facilitate the increased supply of skills needed for building decarbonisation and the wider climate transition. 	

8.5. Regional Approaches

As with previous sections covering regional approaches towards building decarbonisation, this section shall outline several regional approaches within Sweden that have showed particular initiative and

present opportunities for Government action surrounding building decarbonisation to be improved. Such opportunities may also present opportunities for other organisations to improve upon their own strategies both locally and nationally.

8.5.1. Stockholm

On the 25th May 2020 the city of Stockholm adopted its 'Climate Action Plan 2020-2023' [64] outlining the cities plans to achieve a fossil-free Stockholm by 2040. To this end, the city is seeking to further expand upon its climate action (which has been present in Stockholm since 1996 before the true threat of climate change was taken seriously by many) and take the lead in Sweden to inspire other regional authorities to commit further resources to tackling climate change and stimulating renewed decarbonisation efforts. Outlined plans surrounding building decarbonisation cover the city's approach towards decarbonising district heating, improving energy efficiency and phasing out fossil fuels for individual heating systems where detailed measures for 2020-2023 are supplemented by projected emission reductions and information regarding those responsible for ensuring the successful implementation of such measures. Plans also provide specific building related regional targets and associated measures missing from national decarbonisation strategy.

- **Regional Plans** have enabled Stockholm to reduce its greenhouse gas emissions by 60% by 2018 compared to levels in 2000 [64]. This decrease has been mainly attributed to the large-scale replacement of oil boilers with district heating (which has also seen an increased share of renewables in its energy mix) in larger buildings such as apartment blocks and the increased use of heat pumps in private buildings. Energy efficiency improvements have also played a vital role in reducing emissions with energy supply for heating decreasing by 25% between 2000-2018 [64]. Such a decrease is largely due to Stockholm's strict building standards which limit energy intensity to 55 kWh/m² for existing buildings and 45 kWh/m² for new buildings, bringing energy demand down to roughly 30% below that of the Swedish National Board of Housing, Building and Planning's building regulations (table 33) [64]. Continued reductions however, are noted to require increased efforts with regard to further stimulating energy renovations, decarbonising district heating entirely and collaborating with industry to develop procedures for production, follow-up and feedback to ensure the building industry is able to meet Stockholm's ambitious targets [64]. Further work concerning the development of control and adjustment technologies to optimise building energy systems is also a key focus going forward in line with ambitions to further digitise Stockholm's buildings.
- **District Heating** is the primary method by which buildings are heated within Stockholm with over 80% of buildings connected to the district heating network. As such, district heating also contributes the largest share of emissions across the heating sector having made up 85% of total emissions in 2018 (figure 10) [64]. Therefore, recent efforts within Stockholm have focused on the removal of fossil fuels from district heating which have contributed a similar share towards the district heating energy mix since 2000. To this end, coal and fossil oil will be replaced with an increased share of renewable biofuels. In addition to decarbonising district heating, it shall also be expanded to replace the use of existing oil burning boilers within private properties, bringing district heating coverage to near 100% whilst reducing associated emissions down to near zero by 2040. In summary, Stockholm's whole system approach towards heating buildings as well as its strict regional building efficiency regulations and collaborations across industry and business to facilitate improved energy efficiency has positioned the city favourably with regard to achieving its 2040 net-zero target which stands five years earlier than that of the national target. As such Stockholm stands as an example setter across Sweden concerning how to effectively plan, implement and monitor building decarbonisation measures.

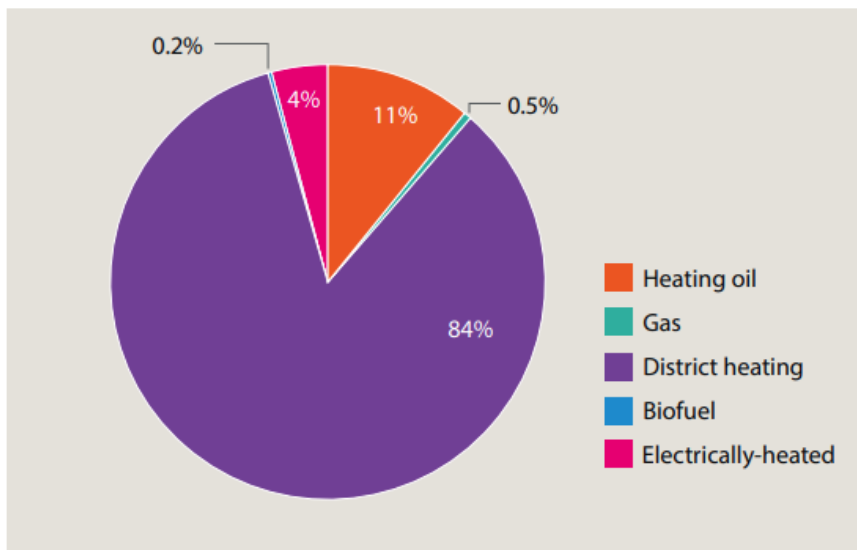


Figure 10: Distribution of greenhouse gas emissions from Stockholm's heating sector in 2018 [64].

- **Plastic Recycling** remains an important focus of Stockholm's building decarbonisation efforts in the spirit of promoting a circular economy whilst acquiring further biofuels for use in district heating. To this end, multiple new plastic sorting plants are to be opened in 2023 to allow for the sorting of waste. In doing so the recycling of eligible plastics will be increased to help reduce unnecessary waste incineration which contributes towards greenhouse gas emissions. Food waste will also be salvaged and used for biogas production to help decarbonise heating [64]. The issue of dealing with unrecyclable plastics derived from fossil fuels remains a challenge however with most of these plastics ending up as waste or being burned. As such the city of Stockholm is paying close attention to developments in this area. The city is also setting requirements for the procurement of recyclable plastics to support a wider market transition away from fossil fuel-based plastics towards those that are recyclable [64]. Improving waste management is an essential part of Stockholm's vision for sustainable housing in which all plastic waste can be recycled and food waste can be converted to biofuel which can then be used to ensure the same buildings heating is clean and renewable. In this way Stockholm takes additional steps towards a whole system approach by enabling the city's waste to become the city's fuel which can then be used for the city's heating.

8.5.2. Gothenburg

In 2019, the Environmental and Climate Committee together with the City Executive Board for Gothenburg updated the city's environmental programme, changing its name to the 'Environment and Climate Programme for the City of Gothenburg 2021-2030' [65] with plans being reviewed once again in 2022. Detailed within would include the city's commitment to becoming an environmentally sustainable city by 2030 with emissions close to zero. Intermediate targets would also be defined for three primary areas including nature, climate and people with goals targeted at building decarbonisation primarily involving the reduction of energy usage and expanded renewable energy production [65]. To achieve such goals, the city would proceed to outline its strategies informed by key underlying ambitions such as to act as a forerunner with regard to regional climate action, develop the circular economy, live sustainably and many others [65].

- **Regional Plans** across Gothenburg centre around reducing regional emissions by 10.3% per year with further aims to reduce consumption-based emissions by 7.6% a year by 2030

[65]. To this end, primary energy consumption per inhabitant has been reduced from 18 MWh in 2010 to 16 MWh in 2018 with further aims to reduce it down to 12 MWh by 2030. Furthermore, energy intensity has been reduced from 133 kWh/m² in 2009 to 117 kWh/m² in 2017 with the aim of reducing it down to 95 kWh/m² by 2030 [65]. With regards to renewable electricity and heating, the share of renewables comprising both regional electricity and district heating has risen from 1.6% to 20% and 35% to 69% respectively between 2010-2018 driven by the city's ambitious target of achieving a 100% renewable share in both areas by 2025 [65]. Additional targets include reducing greenhouse gas emissions associated with new and renovated buildings by at least 50% by 2025 and 90% by 2030 compared to levels in 2020. The city stands well positioned to achieve these targets with the local authority possessing the resources to directly control energy usage in residential buildings and a well-developed district heating network whose energy mix can be easily controlled (figure 11).

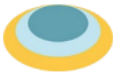


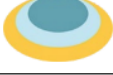

Goal	Control
Environmental goal: Gothenburg's climate footprint is close to zero	
Sub-goal 1: The City of Gothenburg reduces energy use in residential buildings and facilities	
Sub-goal 2: The City of Gothenburg produces energy solely from renewable sources	
Sub-goal 3: The City of Gothenburg reduces the climate impact from transportation	
Sub-goal 4: The City of Gothenburg reduces the climate impact from purchases	



Figure 11: Levels of control the City of Gothenburg has over various environmental sub-goals [65].

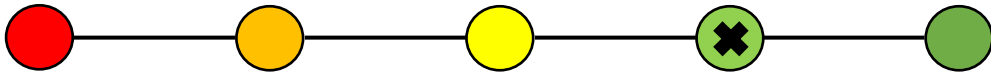
- **Sub-goals** are used extensively to coordinate Gothenburg's climate action plans, utilising a divide and conquer approach to split the city's overarching ambition of becoming environmentally sustainable by 2030 into smaller sub-categories and sub-goals. Each sub-category whether it be focussing on buildings, transport, renewables etc has subsequently received its own dedicated strategy where specific aims, actions, coordinators and stakeholders are detailed (much like Oxford's 'Sprint groups' [9] and Rotterdam's 'Climate round tables' [29]). Such an approach is not new with many of the countries previously covered similarly dividing larger goals into smaller chunks which have subsequently each received dedicated attention. As previously mentioned however, recent Swedish national climate strategy does not utilise this approach as extensively with regards to building decarbonisation, generally choosing instead to focus targets and efforts on wider energy efficiency dealing with multiple sectors as one. Therefore, Gothenburg stands as a regional example to the Swedish Government demonstrating both the benefits of such a system (which include increased transparency, clarity, coordination and appropriate division of labour) and how it can be implemented effectively.

8.6. Summary



Table 35: Overall summary of the Swedish Government strategy to decarbonise its buildings.

Swedish Government Heat and Buildings Strategy	
Strengths	Weaknesses
<ul style="list-style-type: none"> Swedish building decarbonisation strategy has seen much early success with the widespread use of district heating and ground source heat pumps enabling rapid decarbonisation. Many previous decarbonisation targets have been achieved i.e. 40% emission reduction by 2020 thanks in part to building decarbonisation efforts. Policy for energy efficiency is a mature area in Sweden following decades of efforts to improve building efficiency on account of Sweden's cold climate. 	<ul style="list-style-type: none"> In 2022 specific targets and measures relating to building decarbonisation are uncommon. Efforts have been side-lined in recent years with other sectors such as transport taking priority. Sweden has now fallen behind the rest of the EU with regards to its building decarbonisation ambitions and efforts. Ambitions remain insufficient and many additional policies and measures are needed across multiple areas to tackle newly identified hurdles in the way of Sweden's building decarbonisation efforts and it meeting its wider 2030 targets.
Opportunities for Improvement	Threats to Success
<ul style="list-style-type: none"> District heating is already relatively widespread across Sweden and provides the local authorities with direct control of the energy mix used for heating. This enables decarbonisation of the heating supply to happen much easier and at a much higher level than when replacing individual fossil heating systems in buildings. As such continuing the roll-out of district heating and developing additional methods to decarbonise the supply could help further facilitate nationwide building decarbonisation. New solutions regarding waste management present an important step in ensuring that a buildings consumption can become fully sustainable whilst also providing a potential new renewable fuel source for district heating. Adopting a divide and conquer approach towards energy efficiency such that building decarbonisation receives increased attention with areas such as renovation, efficiency and heating receiving dedicated targets and measures could help improve the transparency, clarity and coordination of relevant plans. 	<ul style="list-style-type: none"> Improved enforcement measures are needed to ensure upcoming support schemes are successful at facilitating improved energy efficiency across the building stock. By not providing building decarbonisation sufficient dedicated attention buildings remain at risk of continually being overlooked resulting in Sweden falling further behind other countries in this area. Current levels of climate transparency, if not improved, risk Sweden's climate status remaining ambiguous and subsequently hindering efforts to make improvements efficiently and effectively. Further action is needed to ensure Sweden has access to the skills it needs to facilitate national building decarbonisation.
Transparency	






Swedish Government plans surrounding building decarbonisation along with any subsequent policies and measures are concisely summarised and outlined in full for the public to access however provided details concerning plans and progress could be more comprehensive.






9. Best Practises and Technologies for Building Decarbonisation






With the building decarbonisation strategies of several key developed European nations covered in previous sections, a summary of observed best practises can now be formulated to highlight areas of success and subsequently help both governments and organisations identify opportunities to improve upon their current building decarbonisation strategies. To this end, this section shall attempt to summarise and highlight the most promising policies and measures currently being implemented across various areas relevant to building decarbonisation, discussing policies and measures that have been particularly successful in achieving their intended aims as well as more novel approaches that show significant potential to yield strong results in the future. Additionally, several commonly adopted technologies shall also be discussed to provide an overview of the primary technologies being used to drive building decarbonisation efforts forward together with any associated advantages and disadvantages.




9.1. Government Policies and Measures

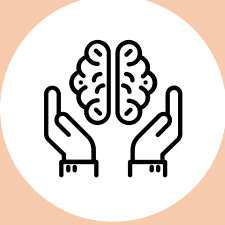





Table 36: Summary table of exemplary Government policies and measures surrounding various areas relating to building decarbonisation.





Area	Policy/Measure /Initiative	Overview	Rating
 <p>Renovation of the existing building stock</p>	<p>Superbonus Scheme</p> <p>Italy</p> 	<ul style="list-style-type: none"> Italy's 'Superbonus' scheme launched in July of 2020 as a subsidy to stimulate residential energy renovations until it is phased out completely in 2025 [66]. The 110% bonus can be claimed up until 31st December 2022 after which time the maximum support offered will be reduced. The scheme acts as a supplement to the country's wider 'Ecobonus' initiative [46]. In the first 8 months following its release, the scheme approved over 122,000 applications providing approximately £17.5 billion worth of support [66]. This sudden uptick in demand provided a boost to the construction sector which generated more than 150,000 new jobs [66]. Several other EU countries have similar schemes in place, but none have been as generous or as successful at stimulating new energy renovations as the 'Superbonus'. The scheme has driven up construction costs however whilst also providing support for new natural gas boilers (if 	

		<p>installation improves efficiency) which has hindered efforts to phase out fossil fuels for heating.</p>	
	<p>Rekorderlig Renovering Method</p> <p>Sweden</p> 	<ul style="list-style-type: none"> • The Rekorderlig Renovering method was developed by members of the Swedish Energy Authority's client network and is a systematic approach towards identifying tailored cost-effective renovation measures to improve the energy efficiency of apartment buildings (which make up 5% of residential buildings within Sweden) [58]. • The aim of the method is to increase the degree of energy efficiency renovations by providing property owners with an overview of the individual needs of their property regarding renovations and energy efficiency improvements [58]. • The method takes into account the financial situation of the property owner who can use the method to determine what combination of measures would be most profitable for them and yield the greatest efficiency improvements over a 20 year period, thus providing them with a basis for decision making regarding energy renovations [58]. • The method has been used as part of the Halvera Mera initiative which aimed to prove the methods ability to identify cost effective measures to reduce the energy consumption of buildings by at least 50%. Improvements varied between buildings although results showed that energy consumption was reduced by 50% or more in 70% of targeted buildings [58]. 	
 <p>Improving building energy efficiency</p>	<p>Energy Efficiency First Principle</p> <p>Germany</p> 	<ul style="list-style-type: none"> • Germany stands as the first European country to adopt an 'efficiency first' principle [67]. • The principle promotes increased focus on energy saving practises that are less expensive and easier to implement with the aim of decreasing the costs of the energy transition whilst increasing its feasibility [67]. • Outlined national strategy discusses extensively how such a principle has been implemented across various areas of Germany's approach towards decarbonisation [39]. • Regarding buildings, the efficiency first principle has supported Germany's building decarbonisation strategy, prompting stricter building standards, 	

		<p>enforcement and legislation, areas for which Germany now remains amongst the leaders in Europe [38].</p> <ul style="list-style-type: none"> Recent improvements to building standards include the mandatory EH 40 standard for Government buildings from 2022 which will soon become a requirement for an EH 55 standard for all new buildings and renovations from 2023 onwards. 	
 <p>Decarbonising heating</p>	<p>District Heating Implementation</p> <p><i>Sweden</i></p> 	<ul style="list-style-type: none"> The primary aims of district heating is to utilise local energy resources which are currently wasted to provide heating via distribution networks. The resulting system possesses a highly flexible energy mix which can be used more efficiently than when used for individual heating systems [68]. Sweden's approach towards district heating stands as a prime example of the fulfilment of such aims with systems able to effectively utilise local heating resources to provide heating through extensive heating networks whilst having a low-environmental impact [68]. Widespread implementation of district heating for use in apartment blocks (accounting for 90% of hot water heating in 2017 – 17% of all heating in homes [58]) has enabled rapid decarbonisation with only 6% of district heating supply coming from fossil fuels in 2017 [58]. Continued efforts are working to reduce the fossil fuel share remaining in district heating to ultimately produce a completely renewable heating solution. Expertise surrounding district heating has positioned Sweden well to remain as a frontrunner in this area whilst supporting the implementation of district cooling solutions which may be particularly relevant for hotter countries. 	
	<p>Hydrogen Exploration</p> <p><i>The UK</i></p> 	<ul style="list-style-type: none"> The UK is aspiring to take a leading role in developing hydrogen technologies and markets [69]. Decades of experience in the production, distribution and storage of natural gas coupled with geological advantages places the UK in a prime position to develop and implement the production, storage and usage of hydrogen gas for numerous purposes [69]. Conversion of the natural gas grid to become fully hydrogen based with new 	

		<p>gas boilers becoming 'Hydrogen ready' is being extensively explored [69].</p> <ul style="list-style-type: none"> • By 2025 plans will be developed to facilitate the completion of a 100% hydrogen heated town by the end of the decade [69]. • Numerous Government funded programmes are underway to explore the potential of and transition towards hydrogen including the Hy4Heat programme which has developed 100% 'hydrogen ready' appliances and components [69]. • Research, innovation, funding and Government interest stand to propel the UK towards fulfilling its ambition of becoming a world leader with regards to the use of Hydrogen gas for areas including heating and the wider decarbonisation of buildings. 	
 <p><i>Circular economy</i></p>	<p>Anti-Waste and Circular Economy Law</p> <p><i>France</i></p> 	<ul style="list-style-type: none"> • In 2020 France adopted its Anti-waste and Circular Economy law taking concrete steps to fulfil its ambitions of promoting the use low carbon construction materials and practises to help decrease the carbon footprint of buildings throughout their lifecycles. • Many policies introduced stand as world firsts such as the banning of the destruction of unsold non-food items which must now be reused, recycled or donated [70]. • The law stimulates societal transformation by fostering increased sobriety and creating new jobs relating to the reuse, recycling or donation of unused products. • New tools have been made available as part of the Law which support construction firms in their eco-design projects, ensuring resource management can be improved from the design stage to the recycling stage [70]. • The law targets consumption practises and public involvement as much as it does prohibitions and additional regulations for companies to ensure the public is being used effectively to implement measures to develop the circular economy. 	

 <p><i>Training and skills</i></p>	<p>Green Jobs Taskforce</p> <p><i>The UK</i></p> 	<ul style="list-style-type: none"> • The UK Government launched its new Green Jobs Taskforce in 2020 with the aim of creating 2 million skilled jobs to facilitate the UK's transition toward net zero emissions by 2050 [71]. • The taskforce will formulate plans to create new long-term, high skilled jobs by 2030 with additional support given to help those in transitioning industries such as oil and gas retrain [71]. • Collaboration with industry will help collate the required skills needed across multiple industries to implement building decarbonisation measures such as home efficiency improvements and the deployment of renewable heating technologies [71]. • At a broader level the task force seeks set a new direction for the wider job market towards a high skill and low carbon workforce such to ensure UK citizens are able to contribute towards and benefit from the UK's climate transition [71]. 	
 <p><i>Public engagement</i></p>	<p>Public Consultations</p> <p><i>Germany</i></p> 	<ul style="list-style-type: none"> • Public energy consultations for residential buildings, non-residential buildings and SMEs facilitate a full inspection of a property/enterprise by an energy efficiency expert who will formulate a report for the owner detailing potential energy-savings and a roadmap for any relevant renovations. • Such consultations have been largely effective at incentivising property owners to carry out energy renovations in recent years with the provided renovation roadmaps proving effective at ensuring property owners understand the various benefits implementing energy efficiency upgrades [38]. • The results of a study looking into the effectiveness of such consultations show small but significant changes in the decision making of homeowners concerning renovation measures [72]. • Due to the significance of energy renovations for Germany's building decarbonisation strategy, energy consultations for the general public remains one of the country's most important and developed mechanisms for facilitating building decarbonisation [72]. 	

	<p>Rénov' Public Housing Renovation Service</p> <p>France</p> 	<ul style="list-style-type: none"> • The Rénov' is France's new public housing renovation service that was released in January of 2022 seeking to combine existing renovation support schemes and incentives into a single programme [73]. • The programme is accompanied by its own national website and telephone number to allow French citizens to access comprehensive advice and support surrounding available financial aid and general renovation inquiries. • Over 1000 dedicated advisors working across over 450 advice centres throughout France work to ensure the new public service can be offered across the nation [73]. • Included services include renovation assessments to identify cost-effective ways of increasing a buildings energy efficiency, advice for the selection of a company to carry out the renovations, support for administrative procedures and advice concerning the provision of eligible financial aid [73]. • Such a scheme shows much potential to help France tackle the primary hurdles hindering its building renovation efforts which include namely its overly laborious administrative process which reduce the effectiveness of financial support schemes and a general lack of awareness amongst the population concerning available building renovation support and procedures. 	
Rating Key			
	Policy/measure/initiative has seen tangible success towards achieving its intended goal.		Policy/measure/initiative shows originality and potential to be successful in the future.

9.2. Technologies

Table 37: Overview of the background, advantages, disadvantages and next steps surrounding heat pumps [74].

Heat pumps	
Overview	Heat pumps are a technology that enables the transfer of heat from one location to another often through the use of a compressor and a circulating liquid or gas refrigerant. Such a technology allows heat from outside sources to be extracted and pumped into buildings for the purposes of heating through a process that delivers up to 300% more heat energy than the energy required to do so. Certain heat pumps also possess dual functionality with the ability to become efficient air conditioners in hotter climates. There are several different types of heat pumps which differ primarily in how they obtain their heat and where from.

	<ul style="list-style-type: none"> • Air Source Heat Pumps are suitable for temperate climates and transfer the heat from the surrounding air to a refrigerant via compression. This refrigerant can then be condensed to distribute the extracted heat throughout a building. • Ground Source Heat Pumps, also known as geothermal heat pumps, extract heat from the ground, which is heated by the sun throughout the day, and are generally more efficient than air source heat pumps due to more consistent ground temperatures. Extraction involves the installation of either a horizontal or vertical array of heat pipes which transfer the heat from the ground/water into its linked building. • Water Source Heat Pumps are suitable for buildings within close proximity to water above 5°C and are capable of extracting heat from the water through a series of water-refrigerant heat exchangers. • Hybrid Heat Pumps can take many forms including systems that work alongside existing natural gas boilers and those that can extract heat from both the air and the ground. The latter enables more efficient operation in which heat is extracted from the ground when the air is colder before operating in reverse when the air heats up. • Absorption Heat Pumps are driven by alternative heat sources such as solar or geothermal heated water rather than electricity however they commonly use natural gas resulting in them often being referred to as gas-fired heat pumps. • Ductless Mini-Split Heat Pumps work in much the same way as a standard air source heat pump however are much smaller units and are used solely for the purpose of heating specific rooms without the need of any linking ducts.
<p><i>Advantages</i></p>	<ul style="list-style-type: none"> • Heat pumps are cheaper to run than oil and gas boilers. • They do not contribute towards the direct emissions of a building and convert energy to heat efficiently. • They are safer than combustion-based systems. • Heat pumps require less maintenance than combustion-based systems. • They can deliver dual functionality providing both heating and cooling. • Heat pumps are very reliable lasting beyond 20 years.
<p><i>Disadvantages</i></p>	<ul style="list-style-type: none"> • Heat pumps often involve high start-up costs. • Heat pumping systems are often challenging and significantly invasive to install. • More research is needed to ensure the refrigerants being used are environmentally friendly and sustainable. • Operation efficiency is weather dependant. • Heat pumps often do contribute to the indirect emissions of a building through their use of electricity preventing them from being entirely climate neutral devices.
<p><i>Next Steps</i></p>	<p>Research surrounding more environmentally sustainable refrigerants, less invasive installation techniques, heat storage and more consistent operation under changing weather conditions stand to increase the feasibility of widespread use of heat pumps going forward. The development of renewable methods to power heat pumps and the decarbonisation of electricity production also remain key challenges to ensure that such a technology can become entirely climate neutral in the future.</p>

Table 38: Overview of the background, advantages, disadvantages and next steps surrounding district heating [75].

<p><i>Overview</i></p>	<p>District heating is the method by which heat generated across numerous locations is transported through a heat network to provide heating and hot water to other buildings. Such a system allows for the flexible integration of multiple energy sources into its energy mix and can thus facilitate a gradual transition away from a fossil fuel heavy energy supply to rely entirely on renewables. Development of district heating has been extensive over the years yielding five distinct generations of district heating technologies. Each generation improves upon the last in some way to meet new requirements concerning compatible energy sources, distribution temperatures, costs, efficiency etc.</p> <ul style="list-style-type: none"> • First Generation district heat networks incorporate steam and waste coal to produce heat which is transported through high pressure steam pipes in concrete ducts at temperatures exceeding 200°C. The process was highly inefficient. • Second Generation heat networks utilise coal and oil from dedicated on site combined heat and power plants (in addition to sources used previously) to generate heat which is used to heat pressurised hot water. This water is then transported at temperatures just above 100°C. • Third Generation heat networks incorporate biomass, industrial waste heat and natural gas into the energy mix, transporting the heat through pre-insulated pipes at temperatures below 100°C. Monitoring and metering are also introduced for better control over the system. • Fourth Generation networks utilise the largest array of energy sources with geothermal, solar thermal and water heat energy being incorporated alongside all previously mentioned sources. Distribution is now achieved through a multitude of specialised methods optimised for heat transportation to numerous destinations, achieving distribution temperatures of around 50-60°C. • Fifth Generation networks phase out energy sources from fossil fuels to rely entirely on renewable sources and electricity. Distribution networks are modular allowing for easier expansion and transport heat at ambient temperatures before being concentrated as required through the use of individual heat pumps. The addition of smart technologies also helps to improve control.
<p><i>Advantages</i></p>	<ul style="list-style-type: none"> • District heating allows for waste heat and heat sources that are unable to heat an individual building on their own to be combined and utilised effectively to provide heating and hot water to buildings. • The energy mix can be easily controlled to replace fossil fuels with renewables. • Provided heating is much more efficient than individual heating systems helping to improve building efficiency. • District heating, once implemented, makes heating much more accessible and affordable helping to reduce fuel poverty.
<p><i>Disadvantages</i></p>	<ul style="list-style-type: none"> • Establishment of district heating has previously required significant upfront costs. • Many current systems suffer from significant heat losses to the ground. • Significant management of current heat networks is required that has subsequently increased operating costs. • Excess heat, generated in the summer for example, is wasted in many current networks. • Current systems only provide heating and do not provide cooling which is becoming more and more desirable.
<p><i>Next Steps</i></p>	<p>Fifth generation district heating networks aim to tackle all of the above stated disadvantages, being cheaper to deploy due the low distribution temperatures,</p>

	<p>losing minimal amounts of energy to the ground and being much easier to control thanks to the addition of smart technologies. Excess heat can also be fed back into the heat sharing network ensuring it is not wasted and cooling features are available allowing buildings to reduce temperatures by adding heat back into the network. Fifth generation systems however are not currently widespread seeing initial deployment within the last five years. As such, much work is being done to stimulate the development and widespread implementation of fifth generation systems to reap its many benefits for the purposes of building decarbonisation.</p>
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Table 39: Overview of the background, advantages, disadvantages and next steps surrounding smart meters [76], [77].

Smart Meters	
Overview	<p>Smart meters replace traditional gas and electric meters and often come accompanied by an in-home display, or IHD, that is capable of displaying near to real time readings detailing electricity and gas usage throughout a building. This enables occupants to keep a much better eye on their energy usage and bills throughout the year. The smart meter will also automatically send usage information to energy suppliers who are connected to the smart network, allowing them to obtain much more resolute information concerning gas and electricity demand across the country.</p>
Advantages	<ul style="list-style-type: none"> • The widespread use of smart meters across a region/country helps to reduce its dependence on fossil fuels by enabling energy suppliers to better match energy supply with demand i.e. only using additional fossil fuels alongside renewables when necessary. • Smart meters enable easier detection of power surges and outages facilitating quicker response times and fixes. • Meter readings are submitted automatically to the supplier. • Improves consumption awareness by enabling users to track their usage, bills and unit costs throughout the day. • Improved awareness can incentivise users to change their usage habits to save costs and consume energy more efficiently. • The IHD can be helpful to diagnose faulty devices. • Use of a smart meter allows for a greater selection of energy tariffs that are cheaper and promote the use of renewable and off-peak energy. • Installation is cheap/free and non-invasive for the consumer.
Disadvantages	<ul style="list-style-type: none"> • Efforts must be put in place to ensure enough people adopt smart meters for them to be useful. • Older models can lose smart functionality as newer models and systems are introduced. • IHDs can be inaccurate. • Poor signal can make a property ineligible for a smart meter. • The use of a smart meter does not inherently decrease fossil fuels and reduce bills. • Not all energy suppliers offer smart meters.
Next Steps	<p>An increased rollout of smart meters will help energy suppliers build up a more detailed picture of energy usage across a country and better match supply with demand. The wider use of dedicated tariffs will ensure the information provided by smart meters is being used effectively to modify consumer behaviour, encouraging users to use energy at non-peak times and better utilise renewable energy when it is available. Taking advantage of smart meters to better match supply with demand and modify consumer behaviour can ultimately help energy suppliers, through energy management alone, flatten the energy demand curve</p>

	and subsequently incorporate a larger share of renewables into the energy mix on a near permanent basis.
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Table 40: Overview of the background, advantages, disadvantages and next steps surrounding hydrogen heating [78].

Hydrogen Heating	
Overview	<p>With the decarbonisation of heating playing a major role in decarbonising buildings, an alternative to natural gas boilers is required to heat buildings and provide hot water. One possible solution involves the aforementioned heat pumps, however the replacement of all existing boilers with heat pumps would be highly costly and impractical. Instead, Hydrogen gas exists as a tangible alternative to natural gas with the added benefit of enabling existing gas distribution infrastructure to be put to use. The use of Hydrogen can also be staged by first transitioning to Hydrogen-natural-gas blends before converting entirely to Hydrogen.</p> <ul style="list-style-type: none"> • Hydrogen Gas Boilers would work much like existing natural gas boilers with the possibility of retrofitting existing boilers to become 'Hydrogen ready' remaining a possibility. • Hydrogen Fuel Cell Boilers can provide combined heat and power by burning some hydrogen to produce heat whilst utilising the rest in a Hydrogen fuel cell to produce electricity. These systems remain in their infancy however and are much more costly to install. • Electrolysis is one method of producing Hydrogen gas which involves passing a current through water, splitting it apart to produce Hydrogen gas and only clean Oxygen gas as a by-product (hence why Hydrogen produced this way is known as green Hydrogen). Electricity requirements for this method are significant however and would need to be supplied by renewable sources to ensure such gas was produced in a climate neutral manner. • Steam-methane Reformation is an alternative process which is capable of producing Hydrogen gas in much larger quantities by separating it from methane. This method produces carbon dioxide and carbon monoxide gas as by-products however and therefore requires carbon capture technology to ensure such gases are not emitted into the atmosphere to contribute towards global warming.
Advantages	<ul style="list-style-type: none"> • Hydrogen gas is entirely renewable. • The burning of pure Hydrogen does not release any toxic chemicals as products. • Hydrogen itself is non-toxic. • Hydrogen is very energy dense releasing up to three times more energy than fossil fuel gases. • Shifts towards the use of Hydrogen would necessitate the increased deployment and development of renewable energy production. • The use of Hydrogen for heating will create an entirely new market which will provide thousands of jobs. • Hydrogen boilers are as affordable as standard natural gas boilers for the consumer.
Disadvantages	<ul style="list-style-type: none"> • Hydrogen is highly volatile and thus presents an explosion/fire risk to users and distributors. • Methods for producing Hydrogen are currently expensive with the additional requirements of carbon capture and/or renewable electricity driving up costs further.

	<ul style="list-style-type: none"> • Hydrogen is a very light gas making it difficult to store, requiring high pressures and low temperatures that are difficult and expensive to facilitate. • Hydrogen technology is entirely new with many unknowns and much more research needed to successfully and effectively implement Hydrogen heating.
<p><i>Next Steps</i></p>	<p>Governments must now work to support research and development surrounding areas relating to Hydrogen production and storage particularly to ensure countries are able to tap into this energy rich, renewable resource to decarbonise building heating systems. Real world trials, where districts are constructed that are heated entirely with Hydrogen, must also continue such to reveal important information about how Hydrogen heating can be safely implemented and scaled up to a national level.</p>

10. Summary and Key Findings

This report has explored the various approaches of several developed European nations towards building decarbonisation such to provide an overview of efforts in 2022 and to extract a series of best practices and key technologies such to aid governments and organisations in improving upon their building decarbonisation strategies. To this end, stated objectives, policies and measures concerning building decarbonisation have been detailed alongside subsequent critique to highlight areas of both success and those in need of improvement. Regional approaches within the relevant countries have also been considered to discuss approaches being undertaken at the local level which have presented opportunities for each respective Government to improve upon its own decarbonisation strategy. Successful and innovative policies, measures and technologies have then been summarised to provide instances in which identified challenges facing Governments have been addressed.

Key findings reveal Governments and regional authorities are rarely short of ambition with regards to building decarbonisation though often lack both the technical and financial means to effectively implement targeted measures/policies or simply lack them all together. As such, the current challenges faced by many Governments and organisations surround the successful implementation of strong policies throughout existing operations in a way that remains economically feasible and not detrimental to those most vulnerable in society, targeting areas including stimulating energy renovations, developing and implementing sustainable heating, increasing building energy efficiency and developing the required skills. Instances of success outlined in section 9.1 highlight individual schemes (relevant to six key areas surrounding building decarbonisation including the areas mentioned above) which present examples in which challenges in these areas have been effectively addressed, setting examples for other countries to learn from and improve upon. Section 9.2 builds upon this further by exploring key technologies for driving building decarbonisation forward, covering heat pumps, district heating, smart meters and Hydrogen heating. In summary, for Governments and organisations looking to improve upon their decarbonisation efforts the following key findings are relevant:

- Financial incentives that ensure building energy renovations will yield immediate financial benefits coupled with easy access to personalised consultations and advice for property owners have been effective at stimulating increased energy renovations.
- Substantiated guiding principles concerning building energy efficiency have been successful at facilitating improvements to the requirements of building efficiency standards, the enforcement of such standards and renovation legislation, ensuring that when renovations are carried out they are effective at increasing the energy efficiency of the building.
- In addition to the roll-out of smart meters, it is widely recognised that the use and development of heat pumps, district heating and to a lesser extent Hydrogen heating will play a significant role in building decarbonisation with the implementation of district heating having already enabled rapid decarbonisation in countries such as Sweden.
- Comprehensive initiatives concerning training and reskilling to produce a new workforce to implement building decarbonisation measures, such as the 'Green Jobs Taskforce' seen in the

UK, will be needed to ensure that the skills are available to facilitate building decarbonisation whilst also ensuring that labour is effectively reallocated from fossil fuel industries and that those within such industries are able to benefit from the green transition.

- Wider efforts aimed at supporting a circular economy and increased environmental sobriety should not be neglected to ensure that buildings can become climate neutral across their entire lifecycle through improved construction practises/materials, occupants' behaviour and end of life recycling.

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12. Appendix

Appendix A: UK Government Roadmap and Policy Approach

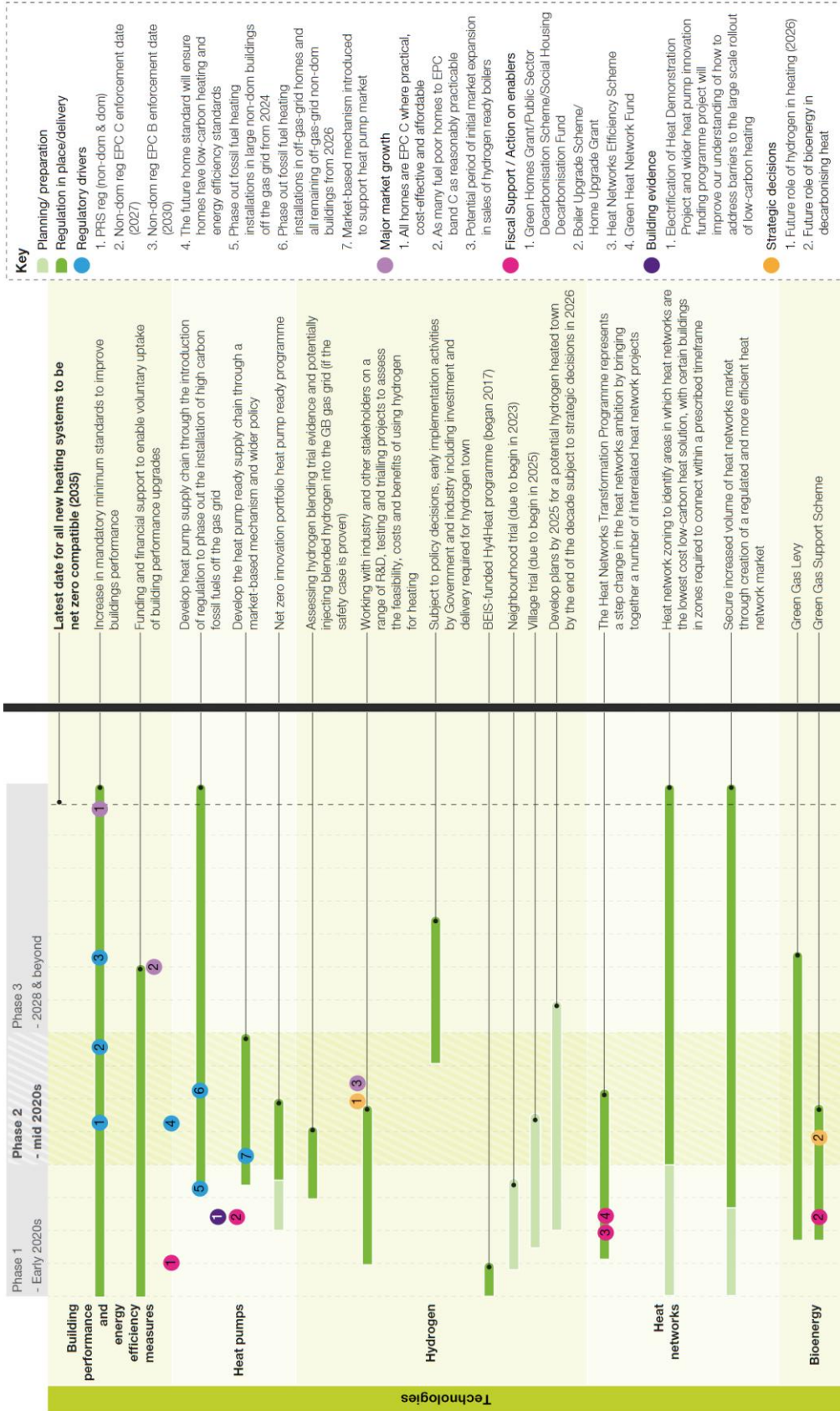


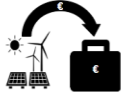



Figure A1: UK Government roadmap and policy approach covering the period 2020-2028 [1].

Appendix B: RAP Summary of Options for Reform of Heating Energy Taxes and Levies

Table B1: Summary table of options considered by several European countries to reform taxes and levies for heating energy [10].

	Option	Description	Examples	Advantages	Disadvantages	Key considerations
	Lower tax on electricity for heating	Lowering the tax rate applied to electricity that is used for heating	Denmark	Simplicity No negative impact on low-income customers	Loss in revenue If tax rate is low to start with, impact is limited	Potential for incentivising excessive electric resistive heating
	Shift levies to fossil fuels	Levies are shifted from electricity to fossil fuels	Netherlands Considered in UK	Simultaneously lowers cost of clean heating and increases cost of fossil heating	Impact on low-income customers using fossil fuels	Need to ensure low-income customers are not disadvantaged, and protected from impact
	Shift levies to public budget	Levies are shifted to the public budget	Germany	No negative impact on low-income customers	Additional cost item in public budget	Potentially less stable funding for clean energy programmes previously funded through levies
	Environmental taxation	Fossil fuels are taxed based on environmental impacts	Swedish carbon tax	Simplicity Source of additional revenue to support heat decarbonisation	Impact on low-income customers using fossil fuels	Need to ensure low-income customers are not disadvantaged, and protected from impact

Appendix C: Summary Table of Support Instruments Outlined in Germany's LTRS

Table C1: Summary table of support instruments outlined in Germany's Long Term Renovation Strategy [34].

Programme/initiative/project	Cost-effective concepts and trigger points	Policies and actions for cost-effective comprehensive energy-efficient refurbishments	Policies and actions for worst-performing buildings	Diverging incentives	Cases of market failure	Reduction of energy poverty	Policies and actions for public buildings	Incentives for the use of smart technologies	Initial and continuing training of experts	Wider benefits of refurbishment	Measures to support the mobilisation of investment
Tax support for energy-efficient refurbishment measures in	✓	✓	✓		✓			✓		✓	✓
CO ₂ building refurbishment programme	✓	✓	✓	✓	✓		✓	✓		✓	✓
Market incentive programme to support renewable energy measures in the heating market (MAP)	✓	✓	✓	✓	✓		✓	✓			✓
Energy Efficiency Incentive Programme (APEE)	✓	✓			✓			✓			✓
Support programme for heating optimisation (HZO)	✓	✓	✓		✓		✓	✓			✓
Support strategy on energy efficiency and renewable heating	✓	✓	✓		✓		✓				✓
Energy-efficient urban redevelopment	✓	✓	✓		✓		✓	✓			✓
Meeting user requirements and effective interaction with the building: Social city			✓		✓						✓
National Climate Initiative (NCI)			✓			✓	✓				✓

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One-stop shop and guide to energy efficiency support		✓			✓						✓
The 'Germany Does It Efficiently' campaign	✓	✓			✓						✓
The 'House Turnaround' campaign	✓	✓			✓						
Instruments and measures for inefficient buildings: Energy certification			✓		✓		✓				✓
Advice on energy-saving contracting	✓	✓	✓		✓						✓
Energy consultancy services for non-residential buildings of local authorities and non-profit organisations (EBK)	✓	✓	✓		✓		✓	✓	✓	✓	✓
Energy advice in small and medium-sized businesses	✓	✓			✓			✓	✓	✓	✓
Energy advice for residential buildings (on-site advice, building renovation passport)	✓	✓	✓		✓			✓	✓	✓	✓
Energy advice from consumer centres	✓	✓	✓		✓	✓		✓		✓	✓
Inspection tool for air-conditioning and ventilation systems	✓	✓	✓		✓		✓	✓		✓	✓
7th Energy Research Programme (ERP)								✓			✓
Energy transition construction programme								✓			
Future of Construction innovation programme								✓			✓
Support programme for Heating Network Systems 4.0	✓						✓	✓			✓
Federal funding for the Smart Meters pilot programme	✓				✓			✓			✓
Serial renovation	✓				✓	✓	✓	✓	✓		✓
Energy Efficiency Networks Initiative							✓				✓
EnEV		✓	✓		✓						✓
Right of tenancy				✓	✓						
Ordinance on Small and Medium-Sized Combustion Plants (1st Federal Emission Control Ordinance (1. BImSchV))			✓		✓						
Instruments and measures for inefficient buildings: National efficiency label for old heating systems			✓		✓					✓	✓

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Specialised portal for energy-efficient construction and refurbishment.					✓		✓		✓	✓	✓
Qualifications of energy consultants					✓		✓		✓		✓
Quality assurance in the funded energy advice									✓	✓	
Quality assurance of training									✓		
Qualification testing for energy consultants									✓	✓	
Inter-company vocational training in skilled trades									✓		
Continuing training to become master craftsman									✓		
SME Initiative Energy Transition and Climate Protection – Support of Energy Scouts					✓				✓		
Assistance for energy advice in the local authority non-residential buildings area					✓		✓				

Appendix D: Existing Financial Measures Within Italy and Associated Areas of Intervention

Table D1: Existing financial mechanisms within Italy and their associated areas of intervention as outlined within Italy's 2021 'Strategy for Energy Retrofitting of National Building Stock' [46].

	a. Aggregation of projects	b. Reduction of perceived risk	c. Public funding	d. Guiding investment in an energy-efficient public building stock	e. Accessible and transparent advisory tools and energy advisory services
The National Energy Efficiency Fund		X	X (Invitalia)	X	
Energy efficiency fund for schools				X	
Fund for the purchase and/or renovation of real estate ('Plafond casa' initiative – energy retrofiting) ⁶⁵	X	X	X (CDP)		
First Home Guarantee Fund (Fondo Garanzia Prima Casa) ⁶⁶			X (MEF)		
Conto Termico		X		X	
Ecobonus	x			x	
Energy Performance Contract	X	X			
Green bonds ⁶⁷	x			x	x
Crowd-funding ⁶⁸	x			x	
Initiatives with structural funds ⁶⁹		X			x
One-stop shop ⁷⁰	X				
White certificates			X		