DECEMBER 2022

Decarbonising heat in Britain's buildings

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Foreword

As I write this in late 2022, our energy system is in crisis. Russia's invasion of Ukraine has brought our energy security into stark relief, as households face soaring bills driven by volatile global gas markets, and National Grid warns of potential blackouts in the winter with demand for gas outstripping supply.

Politicians are grappling with these challenges, proposing everything from fracking and new North Sea oil and gas licenses to insulation and a nationalised, renewables-based energy company. Beyond these immediate dilemmas, the clock to net zero is ticking and we are running out of time to limit global warming to 1.5 °C. We need long term solutions to these dual crises which end our dependence on fossil fuels, reduce overall energy demand, and support our net zero targets.

The UK has one of the oldest and least energy efficient building stocks in Europe, and some 88% of homes are still heated by natural gas. Changing the way we use energy in our buildings, particularly decarbonising heating, is an essential part of the UK's transition to a secure, sustainable energy system.

Much of the transformative technology which can help turn the tide already exists. What is required is a coherent and cogent policy direction, backed up with the right resources.

Alongside low carbon technologies, improving the energy efficiency of our building stock through measures such as insulation will be absolutely critical to reducing our demand for energy and ensuring supply for those who need it. Beyond energy security, we know from our work on the Cost of Poor Housing that tackling domestic energy efficiency could save the NHS up to £857m per year in treatment costs relating to excess cold, and is key to ensuring that everyone can live in a warm, safe, comfortable home.

We must not shy away from the fact that decarbonising heat in our buildings will require significant investment from the Government, but record gas prices and unprecedented intervention to support households means that the economic case for this investment has never been so strong.

Add to this fact that investment will bring considerable opportunities for innovation, job creation and economic growth, and the case becomes even clearer. If we act now, Britain has a unique chance to lead the world in this transition.

For over a century, BRE has developed science-led solutions to the challenges our built environment faces, contributing to a thriving and sustainable world. Decarbonising heat in buildings is the next major step to make our buildings fit for 2050 and beyond, and I am pleased to be able to set out our vision for this journey – the steps we must take, the technologies to use, and the policies that will support us.

Gillian Charlesworth
Chief Executive, BRE

Executive summary

This paper is based on a thorough review of the current evidence and literature on the subject of heat decarbonisation. We have provided an analysis of the current policy direction as well as a number of recommendations which we believe will deliver decarbonisation more effectively. We note that the policy discussion in this report focuses on the UK Government. Many policy areas relating to heat in buildings are devolved, and in Scotland, Wales, and Northern Ireland different policy steps may be taken.

Context

- At present, heating our buildings makes up nearly a quarter (23%) of the UK's total greenhouse gas emissions. Tackling this will be crucial to achieving net zero by 2050.
- Heat decarbonisation across the UK's building stock – changing away from oil and gas boilers – is essential to ensure the long term security of our energy system, and will be key to unlocking market growth, creating green jobs, and mitigating against energy price volatility.
- **There are three steps to decarbonising buildings:**
  1. Improving the energy efficiency of our buildings.
  2. Installing low carbon heating systems in homes, business premises and communities.
  3. Introducing smart, flexible heating technologies.
- Heat pumps are likely to be the dominant low carbon heating technology. Some may work as hybrids alongside other fuels, at least in the transition period to net zero. Hydrogen may also play a role in decarbonisation, as may biofuels. Many more properties will get their heat from networks, rather than having their own individual heating system.
- Property markets are starting to reflect the benefits of decarbonised heating but there needs to be a major infrastructure investment on the part of Government. Across many areas, regulation needs to evolve to support the market.

Our recommendations to the UK Government

1. **Accelerate the roll-out of insulation across the UK's housing stock, as an immediate and cost-effective solution to help reduce the energy demand in our homes and buildings**. All routes to heat decarbonisation necessitate improved energy efficiency.
2. **Address the large gaps in energy efficiency support for mainstream home owner-occupiers and small businesses.**
3. **Confirm the strengthened regulatory plan for energy efficiency in both domestic and non-domestic rented buildings**, to give landlords certainty about the steps they will need to take to upgrade the buildings in their portfolios. The Government should introduce a mandatory energy-use benchmarking scheme for large commercial and industrial buildings, which it consulted on in 2021.
4. The UK is far behind comparable European countries in the development of its heat pump market. **The Government's target of 600,000 heat pumps installations per year by 2028 is achievable and necessary but can only be achieved with a major and urgent policy push.**
5. **Increased consumer awareness of heat pumps is essential;**– this should be a focus area for government-supported advice. The training and retraining of heating installers is equally urgent.
6. Government policy needs to consider a wider range of heat pump technologies. **High temperature heat pump technology is evolving rapidly and the government should strengthen advice, information and standards for hybrid heat pumps.**
   Analysts recognise the potential for hybrid heat pumps using biofuels or hydrogen for some harder-to decarbonise buildings.
7. Some heat pumps, such as air-to-air systems, can switch between heating and cooling the spaces they serve – a feature that is increasingly appealing to households as temperatures rise due to climate change. Cooling represents a new source of energy demand in most homes, and policymakers must consider this when designing pathways to decarbonisation. **Passive design measures should be prioritised to combat overheating and offset the need for 'active' mechanical cooling**. For flats, innovation support for communal heat pump technology is needed.
8. Heat and energy planning will be key to allowing local authorities to develop their energy systems according to local needs, conditions, and cost. Engagement from local authorities will be crucial in driving the decarbonisation of our building stock, and BRE is calling for the Government to **clearly define the role of local authorities and city regions in the low carbon transition**, and to provide the support they need to deliver this.

Introduction

For just over 100 years, BRE has worked with the UK Government, advising on the creation of a high quality, safe, and sustainable built environment. Over the decades, we have analysed and tested the building technologies that have transformed the way we live, from bricks and double glazing to the digital building management systems that are used in the largest commercial developments.

With nearly a quarter – 23% – of the UK's 2019 carbon emissions coming from heating buildings[1], decarbonising heat in buildings to eliminate these emissions will be critical to meeting the UK's net zero target and ensuring our buildings are fit for 2050 and beyond.

There is no question that this transition will require significant investment by the UK Government. The Climate Change Committee (CCC) estimated in 2020 that the heat transition in buildings will cost around £360bn over the three decades to 2050[2]. However, many of the costs of the heat transition will be borne by consumers. There is already evidence that the costs of decarbonised heating are being priced in at the top of the market, with leading property company Savills reporting in April 2022 that "more environmentally friendly heating methods such as heat pumps and community heating systems are most prevalent in higher-value areas...Homes with heat pumps demand a 59% premium compared to regional averages."[3]

This comes alongside the wider potential of heat decarbonisation to generate jobs and growth across the UK. The 2021 Heat and Buildings Strategy estimated that "the transition to low carbon buildings could add £6bn GVA (gross value added) and support 175,000 skilled, green jobs by 2030."[4] To deliver this, targeted interventions supporting the households and businesses that cannot afford to pay the upfront costs of the new systems will be key.

23%

of the UK's 2019 carbon emissions came from heating buildings

£6bn

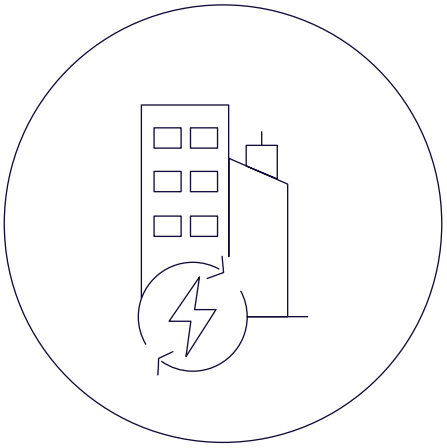
gross value added by the transition to low carbon buildings

175,000

skilled, green jobs created by 2030

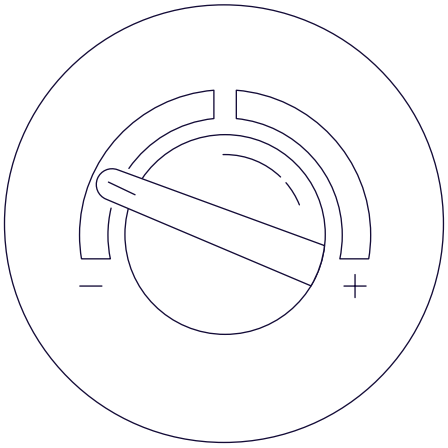
UK Government Heat and Building Strategy, 2021

In practice, decarbonising heat in the UK's buildings will involve three processes:



Improving energy efficiency, thus reducing the need for heating in buildings.

Installing new, low carbon heating systems which might produce heat directly in the building (like a domestic gas boiler would currently) or distribute heat to multiple buildings through heat networks.



Introducing smart, flexible heat which means using evolving control, storage, and digital technologies to balance the demand for heat and the electricity used for heating, to match available supply.

The UK has one of the most diverse stocks of buildings in the world, so it is perhaps surprising that the vast majority of homes (88%)[5] currently get their heat from one source: natural gas. The diversity of our buildings, each with unique needs, will likely mean that by 2050 gas will be replaced by a mix of low carbon heating technologies. This report examines these different technologies and considers their role, alongside energy efficiency and smart, flexible heating systems, in decarbonising our homes and buildings[6].

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[1] Department for Business, Energy & Industrial Strategy, Heat and Buildings Strategy, October 2021, p.22
[2] Committee on Climate Change, The Sixth Carbon Budget, December 2020, p.120
[3] Savills, Buyers paying significantly more for homes with low-carbon technology, as energy prices rise, April 2022
[4] Department for Business, Energy & Industrial Strategy, Heat and Buildings Strategy, October 2021, p.9
[5] English Housing Survey, Energy Report, 2020-21, DLUHC 2022, p.14
[6] We note that many policy issues relating to low carbon heating are devolved, and this paper therefore focuses on relevant UK Government policy in England.

Facilitating decarbonisation

Energy efficiency

National, system level analyses of the technically viable and cost-effective route to net zero show that we must reduce the demand for heat in buildings as a first step. This is the case regardless of the type of low carbon heating systems we adopt across the UK's building stock[7].

Because energy efficiency is so essential for the national energy transition, there are compelling arguments for significant Government intervention to support the energy efficiency market.

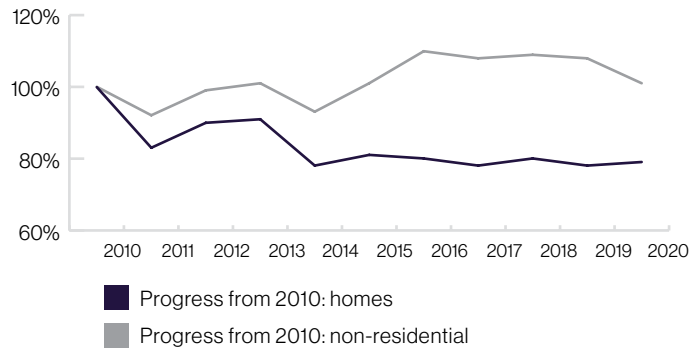
Low income households cannot readily afford – or easily access the finance for – upfront energy efficiency investment. The Government's Energy Company Obligation (ECO), Home Upgrade Grant and Social Housing Decarbonisation Fund provide energy efficiency improvements for low income households and people in social housing.

Even for better-off homeowners or commercial building owners, there is a case for help with the upfront costs. BRE welcomes the new ECO+ programme which widens the households eligible for energy efficiency support. More is needed for all types of homeowner, particularly noting the current fuel bills crisis. And support for insulation needs to come with advice which makes the links between energy efficiency and fitting heat pumps.

Support for business energy efficiency is also critical, particularly for small and medium sized businesses. In Scotland small businesses benefit from energy efficiency advice, energy efficiency audits and interest free loans for improvements of up to £100,000. For participant businesses, the Scottish programme is typically able to identify potential energy savings of 25%, and the programme has achieved a total of £200m savings for Scottish businesses overall[8]. None of this is provided by the UK Government in England.

In both domestic and non-domestic rented buildings, regulation is needed to ensure landlords make insulation upgrades. Energy efficiency is measured on the Energy Performance Certificate (EPC) A-G scale.

Final energy demand in homes and non-residential buildings (Source: CCC,2022*)



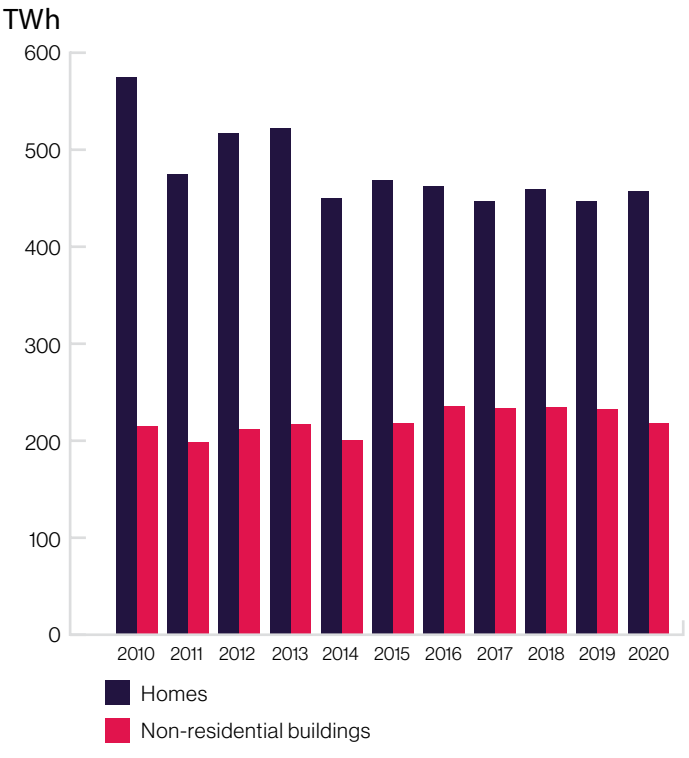


Chart data © Committee on Climate Change 2022 *Progress Report* and Supporting Charts and Data https://tinyurl.com/y8ccs5mr

The Government has consulted on a minimum basic energy efficiency standard which is due to take effect by the late 2020s. Where cost effective this would be set at C for rented homes, and B in rented business buildings. This strengthened regulatory plan for energy efficiency in rented buildings needs to be confirmed, to give landlords certainty about the steps they will need to take to upgrade their portfolios.

To enable the market to drive energy efficiency, timely and accurate data is also vital. For the largest industrial and commercial buildings, the Government has proposed to introduce a national performance-based policy framework for rating energy and carbon performance[9]. This will use energy monitoring data to benchmark the most efficient buildings based on their actual day-to-day energy use. The Government consulted on this plan in March 2021, but no final decision has been made. It will be a major step, and the Government should proceed with its introduction.

Local heat and energy planning

At a regional, city and community scale, heat and energy planning which allows local areas to lead on the planning of their energy systems according to local needs, conditions and cost will be key to determining affordable and effective solutions for heat decarbonisation in buildings.

Some aspects of heat planning can be explained simply. Heat networks are most effective in dense urban areas where buildings with high heat demand are close together. Ground source heat pumps require outside space so will be often more suitable in rural situations. Clean hydrogen will be used for decarbonising industrial processes, so industrial buildings and homes close to large industrial plants may cost-effectively use hydrogen for heating.

A 'whole system' approach to local heat and energy planning which considers the entire energy system, including distribution, transmission, generation, and regulation, is essential if we are to transition to decarbonised heating cost-effectively. The Energy Systems Catapult estimates that costs of decarbonising heat will be two to three and a half times lower from a planned approach deploying different technologies in different areas, than a blanket approach using one technology[10]. The new Future Systems Operator (FSO) proposed in the Energy Security Bill[11] will be an important step towards this. The FSO will "bring together the planning for the electricity and gas system...into a single institution to enhance our ability to transition to a zero carbon energy system."[12]

There is a political challenge to build capacity within councils and city regions to deliver energy planning. BRE is calling for the Government to clearly define the role of local authorities and city regions in the low carbon heat transition, and to provide the support they need to deliver this. We also need to see a clear plan to further align the planning system with net zero targets.

Smart, flexible heat

Smart, flexible heat in buildings means using energy storage, control, and digital technologies to time-shift demand for heat and for the electricity used for heating. By enabling and rewarding consumers to capitalise on times of lower-cost energy, these technologies can align heat energy demand with available supply. Smart, flexible heat technology in buildings reduces constraints on the energy network, and costs for consumers and the overall system. There are various technologies that can deliver smart, flexible heat in buildings, including smart meters, smart heating controls, and building-scale battery technologies for storing heat or electricity.

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7 See for example Imperial College for the CCC, Analysis of Alternative UK Heat Decarbonisation Pathways, August 2018, p.39, which states, "energy efficiency is of key importance: reducing heat demand by improving energy efficiency of buildings can reduce system costs across all pathways."

8 Business Energy Scotland, Support for Scottish Businesses, 2022

9 Department for Business, Energy & Industrial Strategy, Introducing a performance-based policy framework in large commercial and industrial buildings, June 2021

10 CATAPULT Energy Systems, 2022. Local Area Energy Planning key to minimising decarbonisation costs, 2022

11 House of Lords, Energy Bill [HL], October 2022

12 Department for Business, Energy & Industrial Strategy, Energy Security Bill factsheet: Future System Operator, September 2022

13 Department for Business, Energy & Industrial Strategy and Ofgem, Transitioning to a net zero energy system, July 2021, p.10

14 Department for Business, Energy & Industrial Strategy, Smart Meter Statistics in Great Britain, August 2022, p.1

15 Department for Business, Energy & Industrial Strategy, Maximising Non-Domestic Smart Meter Consumer Benefits, June 2022

This is an evolving element of the transition to low carbon heating in buildings, but the benefits are huge. The Government estimates that the transition to a smart and flexible electricity system will reduce energy system costs by up to £10bn per year by 2050. It will involve mass consumer uptake of new ways of managing and paying for energy in homes and business buildings. [13]

Facilitating smart, flexible heat in buildings will require:

- **Completing the smart meter roll-out in buildings**: This will be key to unlocking smart, flexible energy and heat across the UK's building stock. The deadline for changing to smart meters across the UK's homes and business premises has been repeatedly extended, with energy suppliers now given until 2025 to complete the job. There is still a long way to go: the smart meter roll-out began in 2013 and, in June 2022, 52% of UK homes and non-domestic buildings had smart meters.[14]
- **Unlocking innovation**: The development of smart flexible heat management technologies is the area of the biggest potential innovation for decarbonised buildings. Targeted Government support for innovation and research to support UK businesses in developing the technology is essential.
- **Ensuring data standards and cybersecurity**: Smart heat technology can involve transfers of energy data between multiple companies involved in the energy system. Setting the standards for robust privacy and cybersecurity is key. At the same time, there is potential to set standards to allow open energy consumption data which is accessible and portable.[15]
- **Regulatory reform**: Developing a smart, flexible energy system involves changing the relationship between consumers and the energy network, allowing energy and data to flow in new ways across the network.
- **Driving consumer acceptability, uptake, and protection**: New types of energy services and energy products will need to be attractive to consumers, and provide effective consumer protection, particularly for low income households.

[7] See for example Imperial College for the CCC, Analysis of Alternative UK Heat Decarbonisation Pathways, August 2018, p.39, which states, "energy efficiency is of key importance: reducing heat demand by improving energy efficiency of buildings can reduce system costs across all pathways."

[8] Business Energy Scotland, Support for Scottish Businesses, 2022

[9] Department for Business, Energy & Industrial Strategy, Introducing a performance-based policy framework in large commercial and industrial buildings, June 2021

[10] CATAPULT Energy Systems, 2022. Local Area Energy Planning key to minimising decarbonisation costs, 2022

[11] House of Lords, Energy Bill [HL], October 2022

[12] Department for Business, Energy & Industrial Strategy, Energy Security Bill factsheet: Future System Operator, September 2022

[13] Department for Business, Energy & Industrial Strategy and Ofgem, Transitioning to a net zero energy system, July 2021, p.10

[14] Department for Business, Energy & Industrial Strategy, Smart Meter Statistics in Great Britain, August 2022, p.1

[15] Department for Business, Energy & Industrial Strategy, Maximising Non-Domestic Smart Meter Consumer Benefits, June 2022

Heat pumps

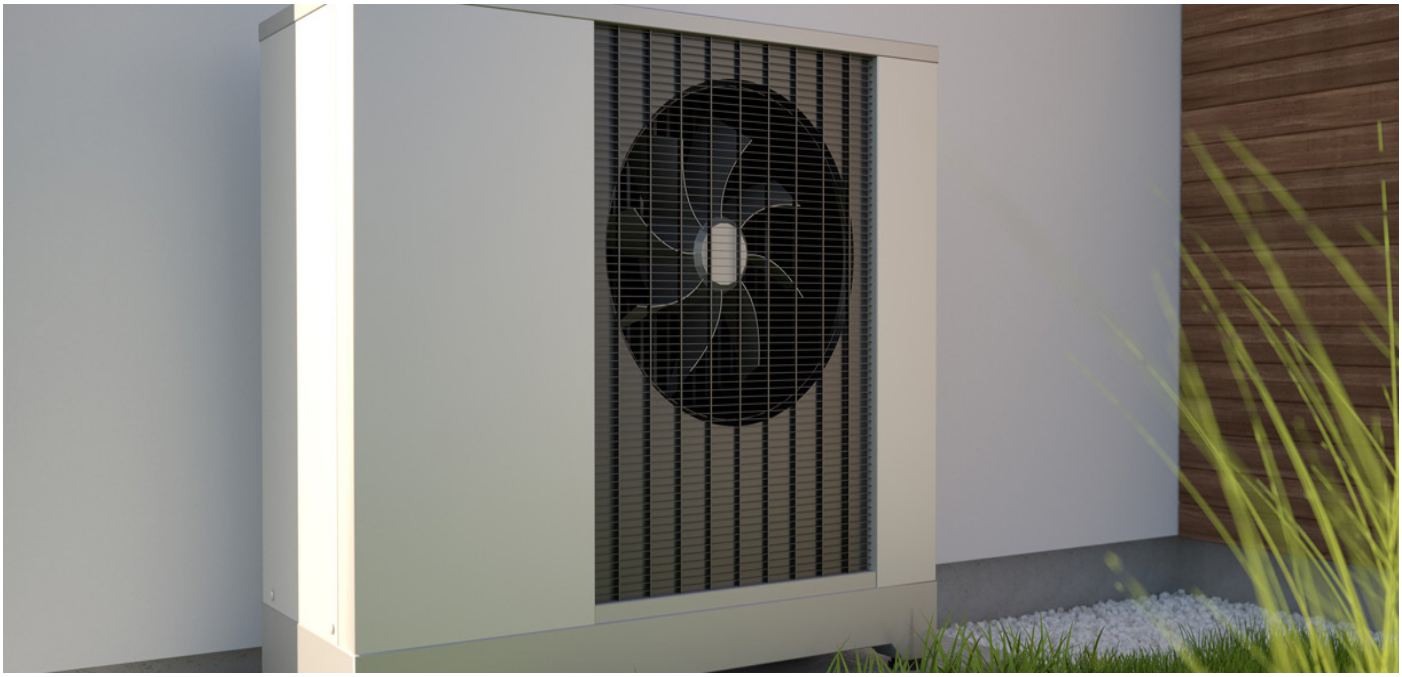
Heat pumps take ambient heat from the air, ground or a local water source and allow it to be delivered as usable warmth inside a property. With a heat pump, one unit of electricity can be turned into multiple (typically between 1.5 and 4.0) units of heat inside the building. With such high efficiency, the logic of using heat pumps to decarbonise heat is inescapable, as a central element of the switch towards UK-generated clean electricity and away from gas.

Importantly, the operating efficiency of heat pumps depends on the temperature difference between the 'input' source temperature (air, ground, or water) and the output temperature of the heat supplied inside the building. So, heat pumps work most efficiently in settings where a steady, low temperature heat (around 35°C or lower if possible) can meet a property's heat demand.

What does this mean for how heat pumps work in our homes and business buildings? While there will be different heat pump technologies in buildings, to illustrate, we can consider homes using air-to-water heat pumps. Air-to-water heat pumps are the most direct heat pump-based replacement for gas central heating, using a similar wet distribution system of pipes, radiators, or underfloor heating.

Considerations for installing these systems in existing, previously gas-heated, homes are:

- **Insulation is key – well insulated buildings have a lower heat demand which can be more readily met by low temperature heat from the heat pump**. In 2019, half of all homes lacked wall insulation and/or full loft insulation[16] and 14% of homes still had at least some single glazed windows.[17]
- **Appropriate outside space**: This is required for installation of the external unit which harnesses the ambient heat. Some noise is generated by the fans when the heat pump is in operation which can affect suitability in some spaces. Alternatives for blocks of flats or other dense housing could include a single large heat pump serving all the properties in the building.
- **Inside space**: Many homes today use a gas combi boiler which does not require a water cylinder. Most air-to-water heat pumps need a separate hot water cylinder.
- **Larger radiators and/or underfloor heating**: Maximising the benefit of increased efficiency at low output temperatures will usually require larger heat emitters than those used with a gas system which operates at higher temperatures.



[16] Ministry of Housing, Communities & Local Government, English Housing Survey Energy Report 2019-20, pp.14-16

[17] Ibid.

Impacts on bills

There is a complex range of factors that will affect how cost-effective a heat pump is for any individual property and its residents.

Based on May 2022 prices the Climate Change Committee (CCC) concluded that, "our estimates suggest that the average heating bill for a heat pump is around 10% higher than for a gas boiler."[18] However, the current gas price crisis has seen rises in both electricity and gas bills[19] and new analysis conducted by BRE which accompanies this report suggests that the recent changes to tariffs are making electric powered heat pumps comparable in running costs with efficient gas boilers. Prices are currently very volatile and in the longer term, policy changes to the balance of levies on gas and electricity bills may be needed to definitively shift the balance in favour of heat pumps.

Heat pumps can be successfully installed in the large majority of homes and there is no type of home that is in principle unsuitable for a heat pump. Still, older homes with lower levels of insulation can pose more challenges to design a suitable system. Compared to a home of the same shape and built form, a less well insulated home will need a bigger heat pump system[20] that will cost more to install and run: this is also true of gas boilers.

There are cost considerations beyond the upfront installation (and corresponding heating system modification) costs of the heat pump and its annual running costs. Energy bills are made up of standing charges and charges for each unit of energy used. Homes that don't use gas will not pay gas standing charges. Heat pumps can also work with hot water storage systems, so they can function at times when electricity is available at cheaper tariffs – storing the heat for use when it is needed.

Implications for embodied carbon

There is a valid question about the carbon emissions that will be generated from making and fitting new heating systems across the country. However, heating is such a large part of our day-to-day energy use that the operational emissions from our current fossil fuel heating systems are significantly greater than the embodied carbon associated with the manufacture and installation of replacements.

The Chartered Institution of Building Services Engineers (CIBSE) has compared the whole life carbon implications of different heating systems in one typical home. This includes the total emissions associated with making a heating system, the energy it uses for heating throughout its lifetime, and its disposal. They found that whole life emissions were around 64% lower using a low carbon air source heat pump than a standard gas boiler. In future, as more of the electricity that powers heat pumps comes from clean renewable or nuclear generation, this differential will increase even further.[21]

64%

Whole life emissions were around 64% lower using a low carbon air source heat pump than a standard gas boiler

Because the heat pump in the home analysed by CIBSE is so clean in its operation, the whole life analysis shows that over half of the heat pump's small carbon footprint comes from its manufacture. As we decarbonise operational energy it will become increasingly important to assess the whole life carbon emissions associated with manufacture, installation, and disposal of heating systems. This is a key area of focus for BRE.

[18] Climate Change Committee, Progress in reducing emissions: 2022 Report to Parliament, June 2022, p.201

[19] Because the price of electricity is determined by the price of the gas used in large scale electricity generation.

[20] BEIS Electrification of Heat Demonstration Project, Home Surveys and Install Report 2022, 2022, p.42

[21] Chartered Institution of Building Services Engineers, Embodied carbon in building services: Residential heating (TM65.1), December 2021

Heat pumps: technology options

Hybrid heat pumps

Hybrid heat pumps combine heat pumps with another heat source – currently this is typically a fossil fuel boiler. The control system will then use the heat pump when lower levels of heat are needed and when it is efficient to do so and use the conventional boiler during periods of demand when the heat pump would be less efficient (for example, in very cold temperatures where the heat pump alone cannot meet the demand, or when a higher temperature supply is needed to heat a hot water cylinder). Hybrid heat pumps can therefore help to meet heating demands efficiently throughout the year.

Hybrid heat pumps are currently most commonly identified as suitable for reducing the running costs and carbon emissions of rural properties using tanked fossil fuels (i.e., LPG or oil). The Government has stated that these properties will move away from oil and gas heating altogether, though biofuel could be a low carbon replacement.[22]

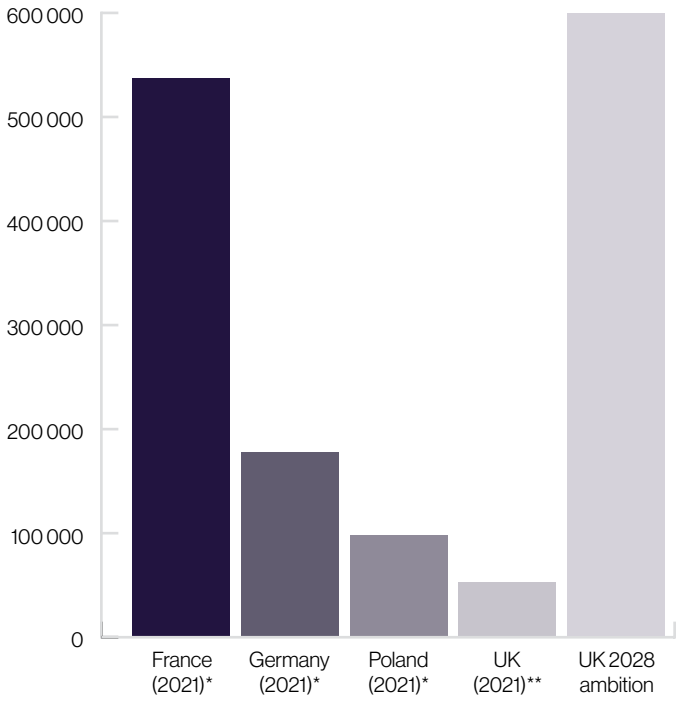
Hybrid heat pumps could also help decarbonise properties connected to the gas grid. Hybrids could be a transitional technology to a full heat pump system, or the residual gas consumption could eventually be replaced with zero carbon hydrogen. In some comparable countries such as the Netherlands, hybrid heat pumps are playing a central role in the heat transition: planned regulations in the Netherlands will prohibit new gas boiler installations from 2026, with hybrid heat pumps being anticipated as the principal replacement technology alongside full heat pumps and district heating.[23]

High temperature heat pumps

Heat pumps that can offer an output temperature of over 65°C have been developed. These can have domestic and non-domestic applications and are designed to replace conventional gas boilers without the need for changing existing radiators. High temperature heat pumps do however currently operate at lower efficiencies and can therefore present higher running costs. In 2016, BEIS reported that these heat pumps are also more expensive (by around 20-35%) than conventional heat pumps.[25]

They may sometimes be a solution for off-gas grid homes of older (e.g., pre-1919 traditional) construction which can be hard to insulate. For these homes, a high temperature heat pump may be a good alternative to oil or LPG-based systems, which are being phased out and for which fuel costs can be high or volatile.[26] Hybrid heat pump solutions as well as biomass could also be viable options in these properties.

Heat Pump annual installations by country



*Data from European Heat Pump Association, 2022. Presentation available at: https://tinyurl.com/3zk75n94

[22] Department for Business, Energy & Industrial Strategy, Phasing out the installation of fossil fuel heating in homes off the gas grid, January 2022
[23] Government of the Netherlands, Hybrid heat pump the new standard from 2026, May 2022
[24] P. Carroll, M. Chesser, P. Lyons, Air Source Heat Pumps field studies: A systematic literature review, December 2020. The system efficiency refers to the units of heat emitted per unit of electricity used. In contrast, a typical standard, low temperature air-to-water heat pump would aim to operate at a system efficiency of around 3.0.
[25] Department for Business, Energy & Industrial Strategy, 2016. Evidence Gathering – Low Carbon Heating Technologies: Domestic High Temperature, Hybrid and Gas Driven Heat Pumps: Summary Report, November 2016
[26] Department for Business, Energy & Industrial Strategy, Phasing out the installation of fossil fuel heating in homes off the gas grid, January 2022
[27] National Grid ESO, Future Energy Scenarios, 2022, p.55

Heat pumps and cooling

With rising temperatures as a result of climate change, many buildings and occupants will increasingly need to deal with high indoor temperatures in summer. Some heat pumps, such as air-to-air systems, can switch between heating and cooling the spaces they serve.

Currently very few UK homes use mechanical cooling, often referred to as air conditioning. The use of mechanical cooling – even through efficient heat pumps – needs to be carefully managed, because with wide uptake it will add significantly to energy demand.

It is important that we do as much as we can to maximise the use of 'passive' design measures including appropriate ventilation provision and solar shading, as this will offset the need for, and increased energy demand and environmental impact of, 'active' mechanical cooling. For new homes, or homes that go through a major refurbishment, it is important that designs limit and protect against significant overheating – for example, by ensuring good window and natural ventilation design, and ventilation systems and controls which manage the way fresh, but not cooled, air comes into the home. Robust assessment of the overheating risk is also vitally important as this ensures that appropriate mitigation measures are identified and installed as part of the build or refurbishment.

Policy considerations

To augment energy security and deliver the UK's net zero target, a very significant and rapid scale-up of heat pump sales is required. The UK is far behind comparable European countries in installation rates.[27]

The Government is aiming for 600,000 heat pump units to be installed per year by 2028. With an estimated 55,000 UK sales in 2021, the target will require a year-on-year increase in sales of 41% between now and 2028. The CCC states that a 47% growth in sales was achieved from 2020 to 2021.

The Government's Boiler Upgrade Scheme is designed to drive the heat pump market, aiming for 90,000 installations over the next three years. Government energy efficiency programmes targeted at lower income households, including ECO, also provide some funding for heat pumps.

The Government's 2021 Heat and Buildings Strategy announced an obligation on manufacturers of fossil fuel boilers sold on the UK market to achieve the sale of a number of heat pumps proportional to their boiler sales in a given period. The introduction of this policy, titled the "Low Carbon Heat Scheme," is planned as part of the Energy Security Bill.

Achievement of the Government's target of 600,000 heat pump sales per year by 2028 is possible. However, building a market of this scale at such speed will require major Government policy focus and investment beyond the current Boiler Upgrade Scheme.

Key policy actions that will be needed to achieve this target are:

- The introduction of the Low Carbon Heat Scheme –a proposed market-based mechanism on fossil fuel boiler manufacturers.
- An increase in scale of the Boiler Upgrade Scheme and evaluation of ECO and the Home Upgrade Grant Scheme to ensure they are effective in supporting the heat pump roll-out, alongside energy efficiency, in low income homes.
- Rapid training and retraining of installers. There are currently only 1,100 qualified heat pump installation companies in the UK,[28] and it is estimated that an additional 12,400 heat pump installers will be required by 2025 and 50,200 by 2030 to support the growing market.[29]
- For local authorities, the scale of heat pump installations makes local heat and energy planning urgent. Heat pumps will add significantly to the demand for electricity on the local grid and local authorities and network operators need to plan how this will be managed.
- Consideration of the long term balance of costs between gas and electricity for consumers is important to promote wider heat pump uptake. Though energy prices will be determined by the Energy Price Guarantee until April 2023, there needs to be a rebalancing of costs on electricity and gas bills in order to promote the electrification of heat.[30] Indeed, HM Treasury has stated that "expanding carbon pricing to gas and reducing policy costs in electricity bills would improve price incentives [for heat pumps]."[31]

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[22] Department for Business, Energy & Industrial Strategy, Phasing out the installation of fossil fuel heating in homes off the gas grid, January 2022

[23] Government of the Netherlands, Hybrid heat pump the new standard from 2026, May 2022

[24] P. Carroll, M. Chesser, P. Lyons, Air Source Heat Pumps field studies: A systematic literature review, December 2020. The system efficiency refers to the units of heat emitted per unit of electricity used. In contrast, a typical standard, low temperature air-to-water heat pump would aim to operate at a system efficiency of around 3.0.

[25] Department for Business, Energy & Industrial Strategy, 2016. Evidence Gathering – Low Carbon Heating Technologies: Domestic High Temperature, Hybrid and Gas Driven Heat Pumps: Summary Report, November 2016

[26] Department for Business, Energy & Industrial Strategy, Phasing out the installation of fossil fuel heating in homes off the gas grid, January 2022

[27] National Grid ESO, Future Energy Scenarios, 2022, p.55

What type of heat pumps do we install?

The Government's policy efforts are focusing on air-to-water and ground-to-water heat pumps. However, a 2021 study[32] for the Government of options for electrifying heating in different house types showed that - in some homes that did not already have a gas boiler and excluding hybrid options - air-to-air heat pumps represented the best whole life cost (taking into account capital, maintenance, and energy costs) over a 15-year investment period.[33]

This poses challenges: air-to-air heat pumps can provide cooling as well as heat and wide uptake could lead to much greater use of cooling in UK homes. Cooling opens a whole new territory of home energy demand which, as identified earlier, would be better managed through planned solar shading, fabric insulation and ventilation improvements.

The Government's 2021 analysis concluded that, "Hybrid combi boilers have lowest costs for flats and houses that already have combi-boilers."[34] Hybrids also offer significant medium-term benefits – their use can switch a significant amount of heat away from fossil fuels to electricity while limiting the sudden increase in demand on the electricity grid that a major 'full' heat pump roll-out would bring. They also give consumers more time to upgrade their insulation and allow them to become familiar with how heat pumps work in the interim. In the longer term, they could potentially work effectively alongside hydrogen in providing heating and – in areas not connected to the gas network – alongside biofuels. The disadvantages for consumers are that they present greater complexity from using two energy sources for heating rather than one. The UK Government is not currently supporting hybrid heat pumps through its Boiler Upgrade Scheme.

Hybrids may be the cost-effective option in some, common circumstances. While as many homes as possible should switch to heat pump-only heating, attention is needed to determine the property types and sectors where hybrids could be a medium- or long-term option.

Many of the questions around heat pump suitability particularly relate to flats. Overcoming technical barriers to communal heat pump systems for blocks should be an area where the Government encourages the market to innovate.

[28] Department for Business, Energy & Industrial Strategy, Heat and Buildings Strategy, October 2021
[29] Heat Pump Association, Building the installer base for net zero heating, June 2020
[30] HM Treasury, Net Zero Review, October 2021, p.51
[31] HM Treasury, Net Zero Review, October 2021, p.7
[32] Department for Business, Energy & Industrial Strategy, Cost Optimal Domestic Electrification, September 2021
[33] Closely followed by electric storage and/or air-to-water heat pumps with low temperature radiators.
[34] Department for Business, Energy & Industrial Strategy, Cost Optimal Domestic Electrification, September 2021

Other technologies

Direct electric heating

Direct electric heating has been part of the energy mix since the 1940s and will continue to play a role as the grid decarbonises, especially where: buildings are very energy efficient; demand is relatively low; and a cheap and clean supply of electricity is available, for example from solar photovoltaic panels. There are various types of direct electric heating, including wall-mounted electric radiators, storage heaters, and infra-red heaters.

Policy considerations

- Direct electric heating systems are affordable to buy and flexible. However, running costs can be high unless the technology is delivered alongside the two other key elements of the heat transition – energy efficiency and the adoption of smart, flexible heating technology.
- The Government has recently consulted on a Smart Mandate that will require new storage heaters (alongside heat pumps and home heat storage units) to be fitted with smart controls, allowing them to respond to signals from the grid or the energy system in the home.[35] This smart technology will be important in unlocking the decarbonisation potential of direct electric heating.

Hydrogen

While hydrogen boilers will run in broadly the same way as current gas boilers, there are still significant infrastructure costs and challenges to overcome. Hydrogen can, to a certain level,[36] be mixed with natural gas and used in our existing gas heating systems.

The Energy Networks Association (ENA) has set a target for Britain's gas companies to deliver 20% hydrogen in the gas network from winter 2023. However more substantial system changes are required to deliver heating systems in buildings that run on 100% hydrogen. It is estimated that £22.2bn of capital expenditure is required to make the UK's existing gas network suitable for hydrogen distribution.[37] This includes replacing low and medium pressure iron and steel pipelines not compatible with hydrogen distribution requirements, and the replacement of domestic gas meters.

A further potential challenge is that hydrogen is likely to be in demand in other sectors and areas of the economy, including industrial processes, industrial heat, energy generation and transport, so the widespread use of hydrogen for heating our buildings may not be a priority and may be subject to price volatility. At a system level, using renewably generated electricity to produce clean hydrogen that is then transported and combusted for heating is less efficient than using electricity directly for heating, particularly using clean electricity to power heat pumps. Nonetheless, from a consumer perspective, switching from natural gas to hydrogen can require smaller changes to homes and commercial buildings so may garner wider consumer acceptance.

Hybrid heat pumps could work with hydrogen, combining the benefits of the two technologies, while requiring fewer major upgrades to buildings to fit the insulation that effective low temperature heat-pump-only solutions need. Trials are underway as part of the wider national programme to assess options for hydrogen heating. For example, a hybrid hydrogen heat pump being trialled in Pembrokeshire uses smart technology whereby, "every 2 minutes the system assesses the energy generation mix and renewable electricity availability on the local grid and requests the boiler to run on hydrogen when unavailable."[38]

£22.2bn

of capital expenditure is required to make the UK's existing gas network suitable for hydrogen distribution.

Policy considerations

Hydrogen does represent an exciting opportunity for the UK energy system and may play a role in heating buildings.

We are only beginning to develop the plans and understand the practical requirements of the development of the hydrogen system in the UK. Under the Government's Hydrogen Strategy,[39] the key decision on the use of hydrogen for heating will be taken in 2026, by which time we need to be well on the way to the delivery of a heat pumps at a large scale.

Hybrid heat pumps using hydrogen are an under-considered element in the transition to net zero and could be used in areas where the electricity network is constrained or where renewable hydrogen is generated and used locally, for example, heavy industry.

It is vital that the pursuit of hydrogen does not distract from the urgent need for energy efficiency and the mass roll-out of heat pumps across the UK's building stock.

Biofuels

Biofuels are energy sources derived from organic materials. Biomethane, which can be derived from food and farm waste via anaerobic digestion, is injected into the gas grid. Solid matter biomass can be burnt to provide low carbon heating. Biofuel technology is evolving and could continue to be a part of the UK's low carbon heating future.

The Government recognises that, currently, solid biomass heating systems have a strategic role in the wider decarbonisation of heat in buildings by providing a suitable alternative for 'hard to treat' buildings, particularly in rural, off-gas grid areas. Rural buildings are often older and hard to insulate, so can be less suitable for standard, low temperature heat pumps that work best in well-insulated properties.

However, despite the suitability of biofuels for rural households, there are other areas of the economy where available biofuels may be needed more urgently, and this may influence supply for heating. The CCC suggests that into the 2030s, biofuels for heating should be limited to "Biomethane produced from anaerobic digestion and other niche uses (as part of hybrid heat pump systems in hard to treat off-gas homes, local combined heat and power systems and small-scale district heat networks)."[40]

Policy considerations

The technology and market for biofuels is evolving and may well be popular with building owners for heating, particularly given the potential for biofuels to "drop in" as replacement fuels in the existing oil and LPG boiler systems that households have been using for decades. Biofuels could also be used with hybrid heat pumps in less well-insulated homes. In Scotland, given the need for biofuels in other parts of the zero carbon economy, the Government has proposed that new buildings should not be allowed to use biofuel-based heating. In England, policy decisions will need to be taken based on the longer-term acceptability of these heating solutions as we move towards the net zero target.

[35] Department for Business, Energy & Industrial Strategy, Delivering a smart and secure electricity system, September 2022
[36] HyDeploy, Phase 2 – Winlaton Trial & Phase 3 – Enabling Policy, 2022
[37] Department for Business, Energy & Industrial Strategy, Hydrogen supply chain: evidence base, November 2018
[38] Smart Energy International, Hydrogen hybrid heating system demonstrated in Wales, March 2022
[39] Department for Business, Energy & Industrial Strategy, UK hydrogen strategy, August 2021
[40] Climate Change Committee, Biomass in a low-carbon economy, November 2018, p.15

Heat networks

Heat networks, providing heat to multiple properties which potentially also draw on multiple heat sources, are an important part of the heat transition as they offer the advantage of economies of scale, maximising the value of heat across communities. Modern heat networks can use clean heat sources – for instance, large-scale heat pumps, biomass and waste heat from industrial processes or power stations – that are unsuitable for connecting to individual buildings. They can work with thermal stores that hold heat reserves at scale, to be deployed when needed.

Policy considerations

The opportunity for heat networks is two-fold. Some heat networks have been in place for many decades using high-carbon heat sources. We need to build on, improve, extend, and decarbonise these legacy heat networks. Secondly, there is the opportunity to develop new low carbon heat networks, particularly using low temperature and waste heat.

As heat networks are developed, policymakers need to provide for effective consumer protection as those connected to heat networks do not have the same choice of energy suppliers as other households and businesses.

Effective oversight of consumer protection will ensure that customers feel confident to sign up to a long-term agreement with a heat network operator, improving the reputation of heat networks. This will in turn give investors greater reassurance in the long-term viability of heat network projects.

The role of local authorities in providing leadership and zoning of heat networks is key. The Government has proposed a regulatory framework for heat networks and to enable heat network zoning in the Energy Security Bill.

The immediate policy priorities for heat networks are, firstly, for the Government to ensure zoning and consumer protection are in place. Provisions for heat networks in the Energy Security Bill are important here. Secondly, the Government urgently needs to ensure that local authorities have the capacity to manage and meet relevant regulatory requirements. This is particularly important for legacy heat networks where the sharp rise in fuel prices has led to new challenges associated with managing the costs of these systems for households. It also makes it more urgent that legacy heat networks transition to low carbon heat.

> “Changing the way we use energy in our buildings, particularly decarbonising heating, is an essential part of the UK’s transition to a secure, sustainable energy system.”
>
> **GILLIAN CHARLESWORTH**
> CHIEF EXECUTIVE, BRE

A BRE view of a likely heat decarbonisation trajectory

The exact mix of technologies we will see in our buildings over the coming 30 years will depend on global markets, the regulatory framework in the UK, and consumer preference. Most importantly, in the short to medium term, the pace of change will be affected by the gas price. If the current high price continues, there will be significant pressure on both Government and building owners to transition sooner rather than later to new heating technologies.

This is one perspective on the decarbonisation journey that informs the thinking of this report:

- **Heat pumps** are likely to be the main technology in the low carbon transition. Installations have already begun at pace in other parts of the world, with France currently installing nearly 500,000 a year. While the pace of this roll-out is significantly slower in the UK, policies introduced in the wake of the Heat and Buildings Strategy will start to drive the market towards the Government's target of 600,000 installations per year by 2028. The technology is mature so as installation techniques are improved and refined the rate of installations is likely to pick up.
- However, heat pumps work best in **energy efficient** buildings, and significant, effective intervention is needed to improve the energy efficiency of the UK's older, often poorly insulated buildings. **Hybrid heat pumps**, where base loads are met by the heat pump and peaks are met by a boiler using another fuel source (currently this is often gas but could potentially later become hydrogen or biofuels), might be a necessary element of the transition – or even the final 2050 energy mix – if energy efficiency does not reach adequate levels.
- **Direct electric heating** has been part of the mix since the 1940s and, as the grid decarbonises will continue to play a role, especially where buildings are very energy efficient and demand is relatively low (for example, in small flats), particularly in combination with local renewables and storage.
- The above, coupled with **local heat and energy planning**, a decarbonised grid incorporating more renewable generation, and **smart, flexible heat** is likely to mean that electricity will become the prevalent energy used for heating in most buildings.
- With effective heat and energy planning and new **heat network** technologies, district heating will increase the use of lower temperature heat networks that can be served efficiently by large scale heat pumps, make use of sources of waste heat where available, and supply heat effectively to well insulated buildings.
- If **hydrogen** – produced in a low or zero carbon way from renewables, or gas with carbon capture – is available on a large scale and at a comparable cost it could form part of our heating future. It is not the most efficient use of renewable electricity, but the investment in infrastructure directly rather than peoples' homes or buildings could be easier for Government and industry to successfully deliver. Hybrid heat pumps could maximise its efficient use.
- **Biofuel-based** heating may be attractive to owners of high-carbon oil and LPG systems, used principally in rural, off-gas grid homes and business buildings, as they switch away from these fossil fuels. Biofuel may be an easier switch than heat pumps for some building owners, and policymakers may need to manage the uptake of biofuels, balancing its use in heating against its use in the wider economy.
- At a regional, city and community scale, **heat and energy planning** which allows local areas to determine the shape and direction of their energy systems according to local needs, conditions and cost will be key to determining affordable and effective solutions. The planned heat network zoning framework, envisaged in the Energy Security Bill, is the first step towards this.
- For governments and administrations at all levels, a **'whole system' approach** to heat and energy planning which considers the entire energy system, including distribution, transmission, generation, and regulation, is essential if we are to transition to decarbonised heating cost-effectively.